KEITHLEY

Model 5802 IEEE-488 Interface

Instruction Manual

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Model 5802 IEEE-488 Interface
Instruction Manual

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Safety Precautions

The following safety precautions should be observed before using this product and any associated instrumentation. Although some instruments and accessories would normally be used with non-hazardous voltages, there are situations where hazardous conditions may be present.

This product is intended for use by qualified personnel who recognize shock hazards and are familiar with the safety precautions required to avoid possible injury. Read the operating information carefully before using the product.

The types of product users are:

Responsible body is the individual or group responsible for the use and maintenance of equipment, for ensuring that the equipment is operated within its specifications and operating limits, and for ensuring that operators are adequately trained.

Operators use the product for its intended function. They must be trained in electrical safety procedures and proper use of the instrument. They must be protected from electric shock and contact with hazardous live circuits.

Maintenance personnel perform routine procedures on the product to keep it operating, for example, setting the line voltage or replacing consumable materials. Maintenance procedures are described in the manual. The procedures explicitly state if the operator may perform them. Otherwise, they should be performed only by service personnel.

Service personnel are trained to work on live circuits, and perform safe installations and repairs of products. Only properly trained service personnel may perform installation and service procedures.

Keithley products are designed for use with electrical signals that are rated Installation Category I and Installation Category II, as described in the International Electrotechnical Commission (IEC) Standard IEC 60664. Most measurement, control, and data I/O signals are Installation Category I and must not be directly connected to mains voltage or to voltage sources with high transient over-voltages. Installation Category II connections require protection for high transient over-voltages often associated with local AC mains connections. The user should assume all measurement, control, and data I/O connections are for connection to Category I sources unless otherwise marked or described in the Manual.

Exercise extreme caution when a shock hazard is present. Lethal voltage may be present on cable connector jacks or test fixtures. The American National Standards Institute (ANSI) states that a shock hazard exists when voltage levels greater than 30V RMS, 42.4V peak, or 60VDC are present. **A good safety practice is to expect that hazardous voltage is present in any unknown circuit before measuring.**

Users of this product must be protected from electric shock at all times. The responsible body must ensure that users are prevented access and/or insulated from every connection point. In some cases, connections must be exposed to potential human contact. Product users in these circumstances must be trained to protect themselves from the risk of electric shock. If the circuit is capable of operating at or above 1000 volts, **no conductive part of the circuit may be exposed.**

Do not connect switching cards directly to unlimited power circuits. They are intended to be used with impedance limited sources. NEVER connect switching cards directly to AC mains. When connecting sources to switching cards, install protective devices to limit fault current and voltage to the card.

Before operating an instrument, make sure the line cord is connected to a properly grounded power receptacle. Inspect the connecting cables, test leads, and jumpers for possible wear, cracks, or breaks before each use.

When installing equipment where access to the main power cord is restricted, such as rack mounting, a separate main input power disconnect device must be provided, in close proximity to the equipment and within easy reach of the operator.

For maximum safety, do not touch the product, test cables, or any other instruments while power is applied to the circuit under test. ALWAYS remove power from the entire test system and discharge any capacitors before: connecting or disconnecting cables or jumpers, installing or removing switching cards, or making internal changes, such as installing or removing jumpers.

Do not touch any object that could provide a current path to the common side of the circuit under test or power line (earth) ground. Always make measurements with dry hands while standing on a dry, insulated surface capable of withstanding the voltage being measured.

The instrument and accessories must be used in accordance with its specifications and operating instructions or the safety of the equipment may be impaired.

Do not exceed the maximum signal levels of the instruments and accessories, as defined in the specifications and operating information, and as shown on the instrument or test fixture panels, or switching card.

When fuses are used in a product, replace with same type and rating for continued protection against fire hazard.

Chassis connections must only be used as shield connections for measuring circuits, NOT as safety earth ground connections.

If you are using a test fixture, keep the lid closed while power is applied to the device under test. Safe operation requires the use of a lid interlock.

If a screw is present, connect it to safety earth ground using the wire recommended in the user documentation.

The symbol on an instrument indicates that the user should refer to the operating instructions located in the manual.

The symbol on an instrument shows that it can source or measure 1000 volts or more, including the combined effect of normal and common mode voltages. Use standard safety precautions to avoid personal contact with these voltages.

The **WARNING** heading in a manual explains dangers that might result in personal injury or death. Always read the associated information very carefully before performing the indicated procedure.

The **CAUTION** heading in a manual explains hazards that could damage the instrument. Such damage may invalidate the warranty.

Instrumentation and accessories shall not be connected to humans.

Before performing any maintenance, disconnect the line cord and all test cables.

To maintain protection from electric shock and fire, replacement components in mains circuits, including the power transformer, test leads, and input jacks, must be purchased from Keithley Instruments. Standard fuses, with applicable national safety approvals, may be used if the rating and type are the same. Other components that are not safety related may be purchased from other suppliers as long as they are equivalent to the original component. (Note that selected parts should be purchased only through Keithley Instruments to maintain accuracy and functionality of the product.) If you are unsure about the applicability of a replacement component, call a Keithley Instruments office for information.

To clean an instrument, use a damp cloth or mild, water based cleaner. Clean the exterior of the instrument only. Do not apply cleaner directly to the instrument or allow liquids to enter or spill on the instrument. Products that consist of a circuit board with no case or chassis (e.g., data acquisition board for installation into a computer) should never require cleaning if handled according to instructions. If the board becomes contaminated and operation is affected, the board should be returned to the factory for proper cleaning/servicing.

SPECIFICATIONS/5802

ANALOG OUTPUT

LEVEL: 1V = 10,000 counts on X1 gain.
1V = 100 counts on X100 gain.
Maximum output voltage = ±4V.

ACCURACY: ±(0.25% of displayed reading +2mV). In X100, 2mV output = 0.2 displayed counts.

RESPONSE TIME: Follows display conversion rate.

OUTPUT RESISTANCE: 1000Ω.

ISOLATION: ANALOG OUTPUT LO is connected to IEEE COMMON. Maximum common mode voltage from IEEE COMMON to earth ground is 30V rms at dc, 50 or 60Hz.

IEEE-488 BUS IMPLEMENTATION

MULTILINE COMMANDS: DCL, SDC, GET, GTL, UNT, UNL, SPE, SPD, LLO.

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

INTERFACE FUNCTIONS: SH1, AH1, T5, TE0, L4, LE0, SR1, RL0, PP0, DC1, DT1, C0, E1.

PROGRAMMABLE PARAMETERS: Range, DRY CIRCUIT TEST,Operate, RELative, POLARITY, DRIVE, TRIGger, Calibration, EOI, SRQ, Status, Data Format, Terminator.

DEVICE-DEPENDENT COMMANDS:

RANGE:

	NON DRY CIRCUIT TEST	DRY CIRCUIT TEST
R0	Auto	Auto
R1	200mΩ	200mΩ
R2	2 Ω	2 Ω
R3	20 Ω	20 Ω
R4	200 Ω	20 Ω
R5	2k Ω	20 Ω
R6	20k Ω	20 Ω
R7	200k Ω	20 Ω

RELATIVE:
Z0 = REL off
Z1 = REL on

OPERATE:
O0 = STBY (Standby)
O1 = OPR (Operate)

POLARITY:
P0 = POL +
P1 = POL −

DRIVE:
D0 = DRIVE (pulsed)
D1 = DRIVE (dc)

DRY CIRCUIT TEST:
C0 = NON DRY CIRCUIT TEST
C1 = DRY CIRCUIT TEST

DIGITAL CALIBRATION:
V ± n.nnnnE ± nn = enter calibration value.

STORE:
L0 = Store calibration constants.

TRIGGER:
T0 = Continuous on Talk
T1 = One-shot on Talk
T2 = Continuous on GET
T3 = One-shot on GET
T4 = Continuous on X
T5 = One-shot on X

EXECUTE:
X = Execute device-dependent commands.

EOI:
K0 = EOI Enabled
K1 = EOI Disabled

STATUS WORD:
U0 = Output status word.

DATA FORMAT:
G0 = Readings and status word with prefix.
G1 = Readings and status word without prefix.

SRQ:
M0 = Clear SRQ Data Mask
M1 = Reading Overflow
M8 = Reading Done
M9 = Reading Done or Reading Overflow
M16 = Busy
M17 = Busy or Reading Overflow
M24 = Busy or Reading Done
M25 = Busy, Reading Done or Reading Overflow
M32 = Clear SRQ Error Mask
M33 = IDDCO
M34 = IDDC
M35 = IDDC or IDDCO
M36 = Not in Remote
M37 = Not in Remote or IDDCO
M38 = Not in Remote or IDDC
M39 = Not in Remote, IDDC or IDDCO

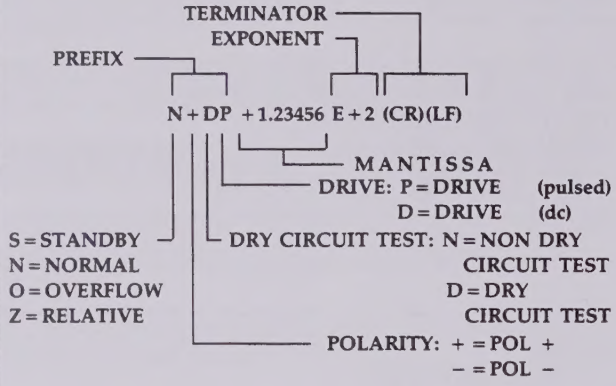
TERMINATOR:
Y(ASCII) = ASCII Character
Y(LF) = CR LF
Y(CR) = LF CR
Y(DEL) = None

TIME FROM TRIGGER TO FIRST BYTE OUT: 350ms to 500ms.

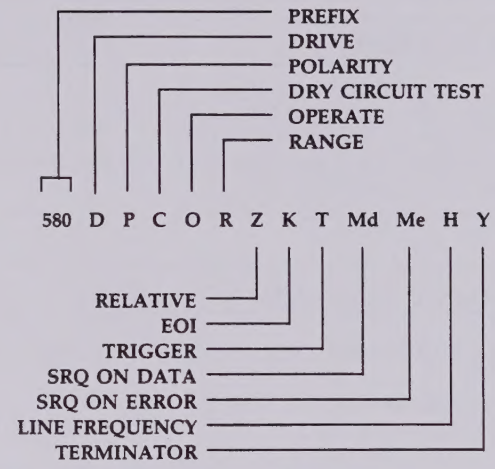
ADDRESS MODES: Talk Only, Addressable.

DATA FORMAT AND STATUS BYTE OUTPUT

DATA FORMAT:



STATUS BYTE OUTPUT:



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SECTION 1
GENERAL INFORMATION

1.1 INTRODUCTION

The Model 5802 is an IEEE-488 interface for the Model 580 Micro-ohmmeter. This interface, which includes analog output, adds extra versatility to the Model 580 by allowing the transmission of data and commands over the IEEE-488 bus. The interface provides all the necessary logic to interface the Model 580 to the bus using standard IEEE-488-1978 protocol.

1.2 INTERFACE FEATURES

Important IEEE-488 interface features:

- With the Model 5802 installed, the Model 580 is able to communicate with other instrumentation using the same IEEE-488-1978 standards.
- A standard IEEE-488 connector that provides easy connection to the IEEE-488 bus.
- An easily-changeable primary address. Although the Model 580 is shipped from the factory with a primary address of 25, the customer can change it by using the five rear panel address switches.
- All Model 580 operation is supported by IEEE-488 programming. In addition, numerous other IEEE-488 commands add operating features not available from the front panel.

1.3 WARRANTY INFORMATION

Warranty information may be found on the inside front cover of this manual. Should it become necessary to exercise the warranty, contact your Keithley representative or the factory to determine the proper course of action. Keithley Instruments, Inc. maintains service facilities in the United States, the United Kingdom and throughout Europe. Addresses for these facilities may be found inside the front cover of this manual. Information concerning the application, operation or service of your instrument may be directed to the applications engineer at any of these locations.

1.4 MANUAL ADDENDA

Information concerning improvements or changes to the instrument which occur after the printing of this manual may be found on an addendum included with this manual. Review these changes before programming the instrument.

1.5 SAFETY SYMBOLS AND TERMS

The following safety symbols and terms are used in this manual and may be found on the instrument.

The ⚠ symbol on the instrument indicates that the user should refer to the operating instructions.

Information associated with the **WARNING** heading explains dangers that could result in personal injury or death.

Information following the **CAUTION** heading explains hazards that could damage the instrument.

1.6 USING THE INSTRUCTION MANUAL

This manual contains all the information you need to connect the Model 5802 to the IEEE-488 bus and program the instrument from a separate bus controller.

The manual is divided into the following sections:

1. Section 2 contains a general description of the IEEE-488 bus and its commands.
2. Section 3 contains information necessary to connect the instrument to the bus and set the primary address.
3. Section 4 contains the bulk of the programming information. General bus commands as well as commands unique to the Model 5802 are covered in detail.

4. Section 5 explains the analog output feature of the Model 5802.
5. Section 6 contains Principles of Operation.
6. Section 7 contains maintenance information such as installation and troubleshooting.
7. Section 8 contains replaceable parts information and applicable schematics and component layouts.

1.7 SPECIFICATIONS

A complete list of IEEE-488 specifications can be found preceding this section.

1.8 UNPACKING AND INSPECTION

The Model 5802 was carefully inspected both mechanically and electrically before shipment. When the Model 5802 arrives, carefully unpack all items and check for any obvious signs of damage.

Report any damage to the shipping agent immediately. Retain and use the original packing material in case reshipment is necessary. The following items are shipped with every Model 5802 order:

Model 5802 IEEE-488 Interface
Hardware necessary for installation
Model 5802 Instruction Manual
Additional accessories as ordered

If you need another manual, order the manual package (Keithley Part No. 5802-901-01). This package includes an instruction manual and any pertinent addenda.

SECTION 2
AN OVERVIEW OF THE IEEE-488 BUS

2.1 INTRODUCTION

The IEEE-488 bus is an instrumentation data bus adopted by the IEEE (Institute of Electrical and Electronic Engineers) in 1975 and given the IEEE-488 designation. The most recent revision of bus standards was made in 1978; hence the complete description for current bus standards is the IEEE-488-1978 designation.

The information presented here is not an elaborate description of a complicated set of standards. Rather, this section briefly describes general bus structure including a bus command outline. Complete IEEE-488 bus information is available from the IEEE and other sources.

2.2 BUS DESCRIPTION

The IEEE-488 bus is a parallel data transfer medium that optimizes data transfer without using an excessive number of bus lines. The bus has only eight data lines, used for data and certain commands. In addition, the IEEE-488 bus employs eight signal lines, including five bus management lines and three handshake lines. Since the bus is of parallel design, all devices connected to the bus have the same information available simultaneously. Each device processes information received from the bus depending on its capabilities.

A typical bus configuration for controlled operation is shown in Figure 2-1. A typical system has one controller and one or more instruments that receive commands and which usually yield data.

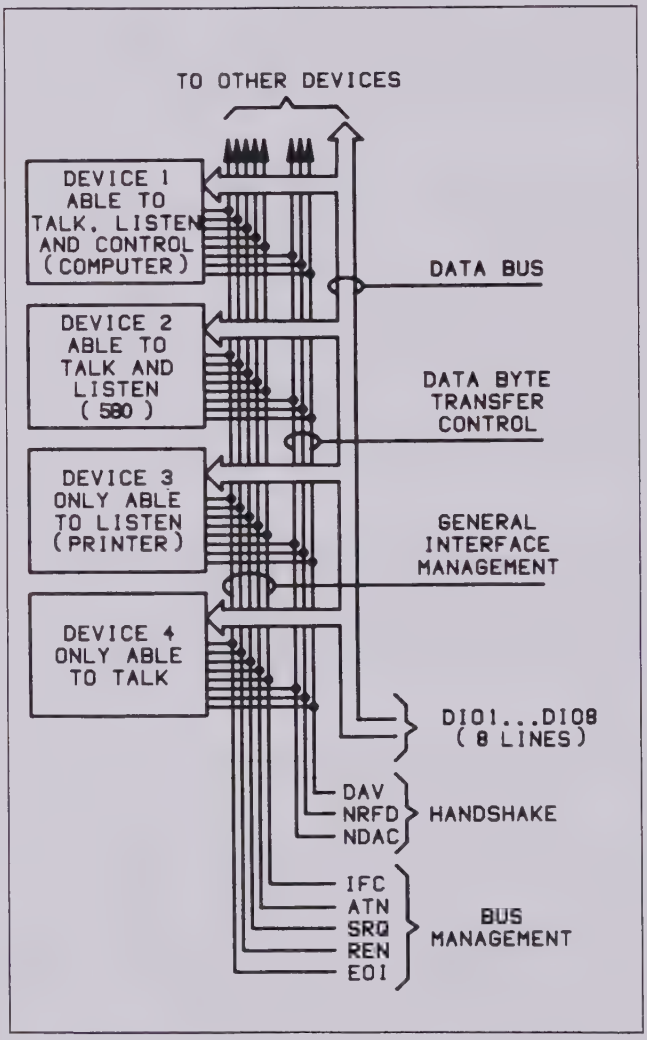


Figure 2-1. IEEE-488 Bus Configuration

Three categories described device operation: controller, talker, and listener. The controller regulates other devices on the bus, the talker sends data, and the listener receives data. A particular device may be a talker only or both a talker and a listener. A system can have only one controller (although control may be passed on to an appropriate device through a special command). Several talkers and listeners may be present depending on the bus's capabilities.

The bus is limited to 15 devices including the controller. The maximum cable length is 20m.

Several devices may listen simultaneously, but only one device at a time may be a talker. Otherwise, communication would be garbled.

Before a device can be a talker or a listener, it must be appropriately addressed. Devices are selected according to their primary address; the addressed device is sent a talk or listen command derived from its primary address. Each device on the bus has a unique address so that each may be addressed individually.

Once a device is addressed to talk or listen, appropriate bus transactions take place. For example, if an instrument is addressed to talk, it sends its data to the bus one byte at a time. The listening device reads this information, and the appropriate software is then used to channel the information to the desired location.

2.3 IEEE-488 BUS LINES

Three types of signal lines are found on the IEEE-488 bus lines: data lines, which handle bus information, and handshake and bus management lines, which ensure proper data transfer and bus operation. Each of these bus lines is "active low" so that approximately zero (0) volts is a logic one (1). The following paragraphs describe the purpose of these lines, which are illustrated in Figure 2-1.

2.3.1 Bus Management Lines

The bus management group includes five signal lines that ensure orderly data transfer. These lines send the uniline commands described in paragraph 2.4.1.

ATN (Attention)—The ATN line is an important management line. ATN line status indicates if controller information on the data bus is to be considered data (set high false) or a multiline command (set low).

IFC (Interface Clear)—The IFC line, set true (low), sends the bus to a known state by sending the IFC command.

REN (Remote Enable)—The REN line, set low, sets up instruments on the bus for remote operation.

EOI (End or Identify)—The EOI line, set low, sends the command to terminate a multi-byte transfer sequence.

SRQ (Service Request)—The SRQ line is set low by a device when it requires service from the controller.

2.3.2 Handshake Lines

The bus uses three handshake lines that operate in an interlocked sequence. This method ensures reliable data transfer regardless of the transfer rate. Generally, the slowest active device on the bus determines the data transfer rate.

Of the three bus handshake lines, the data source controls one and the accepting device controls the other two. The handshake lines are:

DAV (Data Valid)—The source controls the state of the DAV line.

NRFD (Not Ready For Data)—The acceptor controls the state of the NRFD line.

NDAC (Not Data Accepted)—The acceptor controls the state of the NDAC line.

Figure 2-2 illustrates the complete handshake sequence for one data byte. Once data is on the bus, the source confirms that NRFD is high, indicating that all devices on the bus are ready for data. Simultaneously, NDAC is low from the previous byte transfer. If these conditions are not met, the source must wait until the NRFD and NDAC lines have the correct status. If the source is a controller, NRFD and NDAC must remain stable for at least 100nsec after ATN is low. Some controllers have time-out routines to display error messages if the handshake sequence stops for any reason to reduce the possibility of bus hang-up.

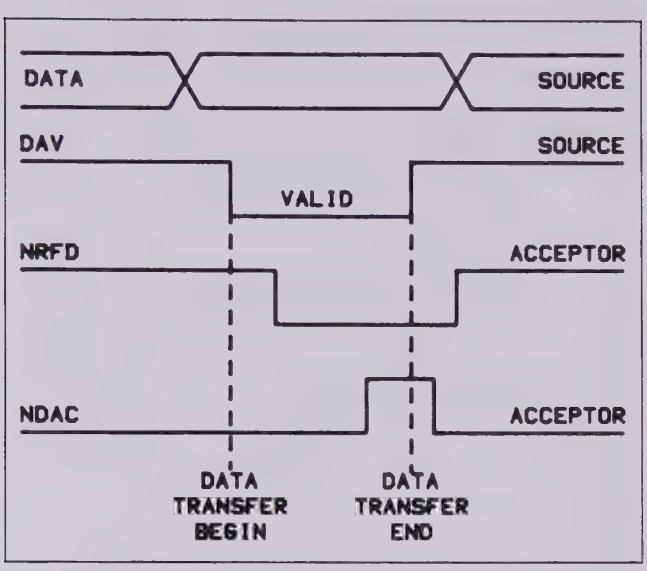


Figure 2-2. Handshake Sequence

Once the NRFD and NDAC lines are properly set, the source sets the DAV line low (data on the bus is now valid). The NRFD line then goes low, and the NDAC line goes high after all devices on the bus have accepted the data. Each device releases the NDAC line at its own rate. The NDAC line will not go high until the slowest device has accepted the data byte.

After the NDAC line goes high, the source then sets the DAV line high, indicating bus data is invalid, and the NDAC line returns to its low state. Finally, each of the devices releases the NRFD line at its own rate until it goes high when the slowest device is ready. The bus is then set to repeat the sequence with the next data byte.

2.3.3 Data Lines

The IEEE-488 bus uses eight data lines that allow data to be transmitted and received in a bit-parallel, byte-serial manner. The eight lines are labeled DI01 through DI08, are bidirectional and, as with the remaining bus signal lines, low is true.

2.4 BUS COMMANDS

This section briefly describes the purpose of the bus commands that control communication between various instruments on the bus. The commands can be divided into three categories.

Uniline Commands—Sent by setting the associated bus line low.

Multiline Commands—General bus commands which are sent over the data lines with the ATN line low.

Device-dependent Commands—Special commands that depend on device configuration; sent over the data lines with ATN high.

Table 2-1. IEEE-488 Bus Command Summary

Command Type	Command	State of ATN Line*	Comments
Uniline	REN (Remote Enable)	X	Set up for remote operation.
	EOI (End Or Identify)	X	Sent by setting EOI low.
	IFC (Interface Clear)	X	Clear Interface.
	ATN (Attention)	Low	Defines data bus contents.
	SRQ (Service Request)	X	Controlled by external device.
Multiline			
Universal	DCL (Device Clear)	Low	Returns to default conditions.
	SPE (Serial Poll Enable)	Low	Enables serial polling.
	SPD (Serial Poll Disable)	Low	Disables serial polling.
Addressed	SDC (Selective Device Clear)	Low	Returns unit to default conditions.
	GTL (Go To Local)	Low	Returns to local control.
	GET (Group Execute Trigger)	Low	Triggers device for reading.
Unaddressed	UNL (Unlisten)	Low	Removes all listeners from bus.
	UNT (Untalk)	Low	Removes all talkers from bus.
Device-dependent**		High	Commands for control of the instrument.

*X = Don't Care
**See paragraph 4.3 for complete description.

2.4.1 Uniline Commands

Uniline commands are sent by setting the associated bus line low. The ATN, IFC and REN commands are asserted only by the system controller. The SRQ command is sent by either the controller or an external device depending on the direction of data transfer. The following is a brief description of each command.

ATN (Attention)—Controller sets ATN when transmitting addresses or multiline commands. Device-dependent commands are sent with the ATN line high (false).

IFC (Interface Clear)—Clears the bus and sets devices to a known state. Although device configurations differ, the IFC command usually places instruments in the talk and listen idle states.

REN (Remote Enable)—Sets instrument up for remote operation. The REN command should be sent before attempting to program the instruments over the bus.

EOI (End or Identify)—Positively identifies the last byte in a multi-byte transfer sequence, and allows variable length data words to be easily transmitted.

SRQ (Service Request)—Asserted by an external device when it requires service from the controller. A serial polling sequence, as described in Section 4, must be used in case of multiple devices to determine which device has requested service.

2.4.2 Universal Commands

Universal commands are multiline commands that require no addressing. All instrumentation equipped to implement the command will do so simultaneously when the command is transmitted over the bus. The universal commands, like all multiline commands, are sent over the data line with ATN low.

LLO (Local Lockout)—The LLO command is used to lock out front panel controls on devices so equipped.

DCL (Device Clear)—After DCL is sent, instrumentation equipped to implement the commands will revert to a known state. Usually, instruments return to their power-up conditions.

SPE (Serial Poll Enable)—The SPE command is the first step in the serial polling sequence. The serial polling sequence is used to determine which instrument has requested service with the SRQ command.

SPD (Serial Poll Disable)—The SPD command is sent by the controller to remove all instrumentation from the serial poll mode.

2.4.3 Addressed Commands

Addressed commands are multiline commands that must be preceded by a listen command before the instrument will respond. The listen command is derived from the device's primary address. Only the addressed device will respond to the following commands:

SDC (Selective Device Clear)—The SDC command is essentially identical to the DCL command except that only the addressed device responds. The addressed instrument usually returns to its default conditions when SDC is sent.

GTL (Go To Local)—The GTL command removes instruments from the remote operation mode. Also, front panel operation will usually be restored if LLO was already sent.

GET (Group Execute Trigger)—The GET command is used to trigger devices to perform a device-dependent action. Although GET is considered an addressed command, many devices respond to GET without being addressed.

2.4.4 Unaddressed Commands

The controller uses two unaddressed commands to simultaneously remove all talkers and listeners from the bus. ATN is low when these multiline commands are asserted.

UNL (Unlisten)—All listeners are immediately removed from the bus when the UNL command is placed on the bus.

UNT (Untalk)—The controller sends the UNT command to clear the bus of all talkers.

2.4.5 Device-Dependent Commands

The instrument determines device-dependent command definition. Generally, these commands are sent as ASCII characters that tell the device to perform a specific function. For example, Z1 places the instrument in the relative mode. For complete information on using these commands with the Model 5802, refer to Section 4. The IEEE-488 bus treats device-dependent commands as data with the ATN line high (false) when the commands are transmitted.

2.5 COMMAND CODES

Each multiline command has a unique code that is transmitted over the bus as 7 bit ASCII data. This section briefly explains the code groups which are summarized in Figure 2-3. Every command is sent with ATN true.

D_7 D_6 D_5 D_4					X 0 0 0		X 0 0 1		X 0 1 0		X 0 1 1		X 1 0 0		X 1 0 1		X 1 1 0		X 1 1 1	
BITS D_3	D_2	D_1	D_0	COLUMN→ ROW↓	0(A)	0(B)	1(A)	1(B)	2(A)	2(B)	3(A)	3(B)	4(A)	4(B)	5(A)	5(B)	6(A)	6(B)	7(A)	7(B)
0	0	0	0	0	NUL		DLE		SP	0	0	16	@	O	P	16			p	
0	0	0	1	1	SOH	GTL	DC1	LLO	!	1	1	17	A	1	Q	17	a		q	
0	0	1	0	2	STX		DC2		"	2	2	18	B	2	R	18	b		r	
0	0	1	1	3	ETX		DC3		#	3	3	19	C		S	19	c		s	
0	1	0	0	4	EOT	SDC	DC4	DCL	$	4	4	20	D	4	T	20	d		t	
0	1	0	0	5	ENQ	PPC*	NAK	PPU*	%	5	5	21	E	5	U	21	e		u	
0	1	1	0	6	ACK		SYN		&	6	6	22	F	6	V	22	f		v	
0	1	1	1	7	BEL		ETB		'	7	7	23	G	7	W	23	g		w	
1	0	0	0	8	BS	GET	CAN	SPE	(	8	8	24	H	8	X	24	h		x	
1	0	0	1	9	HT	TCT*	EM	SPD	)	9	9	25	I	9	Y	25	i		y	
1	0	1	0	10	LF		SUB		*	10	:	26	J	10	Z	26	j		z	
1	0	1	1	11	VT		ESC		+	11	;	27	K	11	[	27	k		{	
1	1	0	0	12	FF		FS		,	12	<	28	L	12	\	28	l		:	
1	1	0	1	13	CR		GS		-	13	=	29	M	13	]	29	m		}	
1	1	1	0	14	SO		RS		.	14	>	30	N	14	∩	30	n		~	
1	1	1	1	15	SI		US		/	15	?	UNL	O	15	←	UNT	o		DEL	

ADDRESSED COMMAND GROUP (ACG)

UNIVERSAL COMMAND GROUP (UCG)

LISTEN ADDRESS GROUP (LAG)

TALK ADDRESS GROUP (TAG)

PRIMARY COMMAND GROUP (PCG)

SECONDARY COMMAND GROUP (SDC)

*PPC (PARALLEL POLL CONFIGURE). PPU (PARALLEL POLL UNCONFIGURE), AND TCT (TAKE CONTROL) NOT IMPLEMENTED BY MODEL 5802

NOTE: D_0 = DIO1 ... D_7 = DIO8
X = DON'T CARE

Figure 2-3. Command Codes

Addressed Command Group (ACG)—Address commands are listed in column 0(B) in Figure 2-3. Column 0(A) lists the corresponding ASCII codes.

Universal Command Group (UCG)—Columns 1(A) and 1(B) list universal commands and the corresponding ASCII codes.

Listen Address Group (LAG)—Columns 2(A) and 3(A) list the ASCII codes corresponding to the primary addresses listed in columns 2(B) and 3(B). For example, if the primary address is set to 12, the LAG byte will correspond to an ASCII(,) command.

Talk Address Group (TAG)—TAG primary address values and the corresponding ASCII characters are listed in columns 4(A) through 5(B).

The preceding address groups are combined to form the Primary Command Group (PCG). The bus also has another group of commands, the Secondary Command Group (SCG). These are listed in Figure 2-3 for reference only; the Model 5802 does not respond to these commands, although other devices may have secondary addressing capability.

NOTE

Commands are normally transmitted with the 7 bit code listed in Figure 2-3. The condition of D7 (DIO8) is usually unimportant, as shown by the "Don't Care" indication in the table. Some devices, however, may require that D7 assume a specific logic state before it recognizes commands.

Hexadecimal and decimal values for each of the commands or command groups are listed in Table 2-2. Each value in the table assumes that D7 is set to 0.

Table 2-2. Hexadecimal and Decimal Command Codes

Command	Hex Value*	Decimal Value
GTL	01	1
SDC	04	4
GET	08	8
DCL	14	20
SPE	18	24
SPD	19	25
LAG	20-3F	32-63
TAG	40-5F	64-95
UNL	3F	63
UNT	5F	95

*Values shown with D7 = 0.

2.6 COMMAND SEQUENCES

The proper command sequence must be sent by the controller before an instrument will respond as intended. The universal commands such as LLO and DCL require only that ATN be set low before the command is sent. Other commands require that the device be addressed to listen first. This section briefly describes the bus sequence for several types of commands.

2.6.1 Addressed Command Sequence

Before a device will respond to one of these commands, it must receive a LAG command derived from its primary address. Table 2-3 shows a typical sequence for the SDC command. The LAG command assumes that the instrument is set at a primary address of 25 (11001).

Table 2-3. Typical Addressed Command Sequence

Step	Command	ATN State	Data Bus		
			ASCII	Hex	Decimal
1	UNL	Set low	?	3F	63
2	LAG*	Stays low	9	39	57
3	SDC	Stays low	EOT	04	4
4		Returns high			

*Assumes primary address = 25.

Note that an UNL command is transmitted before the LAG, SDC sequence. This removes all other listeners from the bus first so that only the addressed device responds.

2.6.2 Universal Command Sequence

The universal commands are sent by setting ATN true and then placing the command byte on the bus. For example, the following gives the DCL command:

```
ATN•DCL
```

Note that both ATN and DCL are on the bus simultaneously. Also, addressing is not necessary.

2.6.3 Device-Dependent Command Sequence

Device-dependent commands are transmitted with ATN false. However, the device must be addressed to listen first before the command is transmitted. Table 2-4 shows the sequence for the following command:

```
Z1X
```

This command, which sets the Model 580/5802 to the relative mode, is described in detail in Section 4.3.5.

Table 2-4. Typical Device-Dependent Command Sequence

Step	Command	ATN State	Data Bus		
			ASCII	Hex	Decimal
1	UNL	Set low	?	3F	63
2	LAG*	Stays low	9	39	57
3	Data	Set high	Z	5A	90
4	Data	Stays high	1	31	49
5	Data	Stays high	X	58	88

*Assumes primary address = 25.

SECTION 3
SYSTEM CONFIGURATION

3.1 INTRODUCTION

This section deals with important hardware and software aspects of IEEE-488 bus operation.

3.2 HARDWARE CONSIDERATIONS

Before the Model 5802 can be used with the IEEE-488 bus, the device must be connected to the bus with a suitable connector. Also, the primary address must be selected, as described in this section. And of course, the Model 5802 IEEE-488 interface must be installed in the Model 580. Refer to Section 7 for installation instructions.

3.2.1 Typical Systems

The IEEE-488 bus is a parallel interface system. When more devices are added, more cables are used to make the desired connections. This flexible arrangement can accommodate simple to extremely complex systems.

Figure 3-1 shows two typical system configurations. Figure 3-1(A) shows the simplest possible controlled system. The controller sends commands to the instrument, which sends data back to the controller.

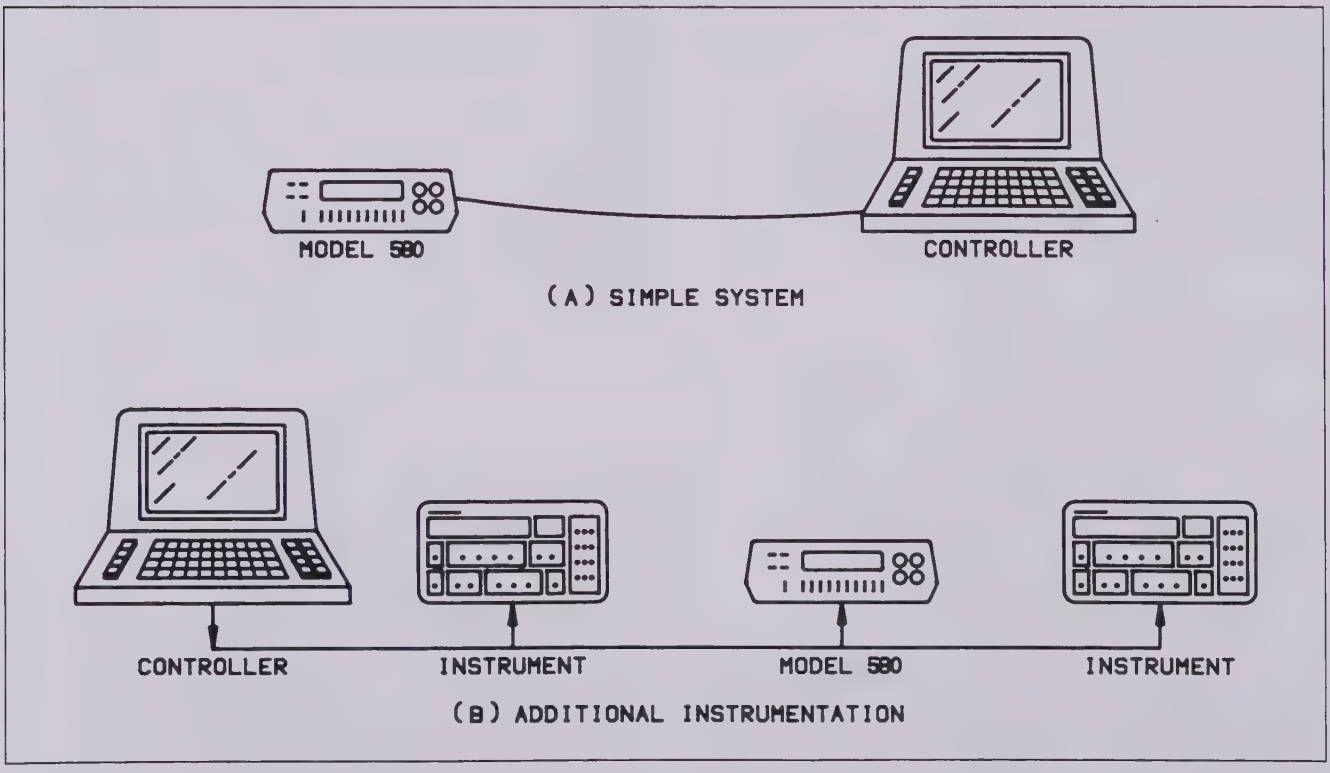


Figure 3-1. System Types

The system becomes more complex in Figure 3-1(B), where additional instrumentation is added. Depending on programming, all data may be routed through the controller, or transmitted directly from one instrument to another. For very complex applications, a much larger computer may be used. Tape drives or disks can then be used to store data.

3.2.2 Bus Connections

The Model 5802 is connected to the bus through an IEEE-488 connector, which is shown in Figure 3-2. This connector can be stacked to allow a number of parallel connections to one instrument.

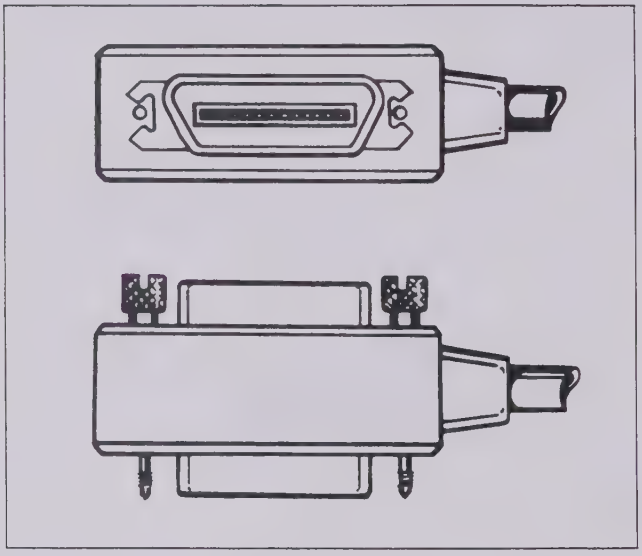


Figure 3-2. IEEE-488 Connector

NOTE

To avoid possible mechanical damage, it is recommended that not more than three connectors be stacked on any one instrument. Otherwise the resulting strain may cause internal damage.

A typical connecting scheme for the bus is shown in Figure 3-3. Each cable normally has the standard IEEE-488 connector on each end. The Keithley Model 7008-6 cable, which is six feet long, is ideal for this purpose. Once the connections are made, the screws should be securely tightened.

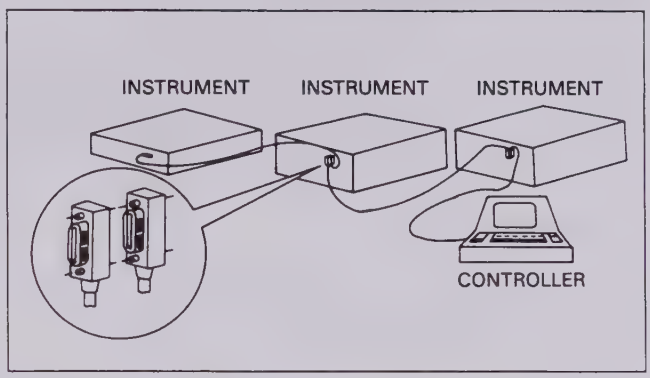


Figure 3-3. IEEE-488 Connections

NOTE

The IEEE-488 bus is limited to a maximum of 15 devices, including the controller. Also, the maximum cable length is 20 meters. Failure to observe these limits will probably result in erratic operation.

Custom cables may be constructed using the information in Table 3-1 and Figure 3-4. Table 3-1 lists the contact assignments for the various bus lines, while Figure 3-4 shows the contact designations. Contacts 18 through 24 are return lines for the indicated signal lines. The cable shield is connected to contact 12. Each ground line is connected to digital common in the Model 5802, but contact 12 within the instrument is left unconnected to avoid ground loops. Refer to Figure 3-5 to locate the connector on the rear panel of the Model 580.

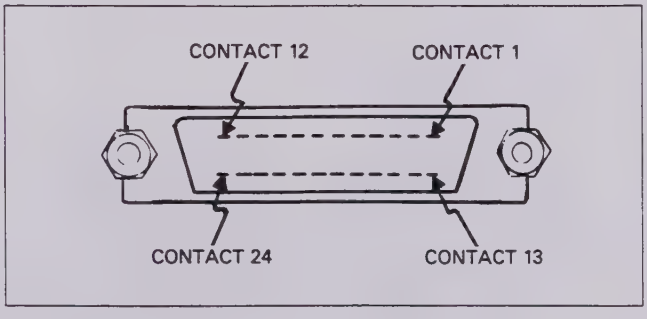


Figure 3-4. Contact Assignments

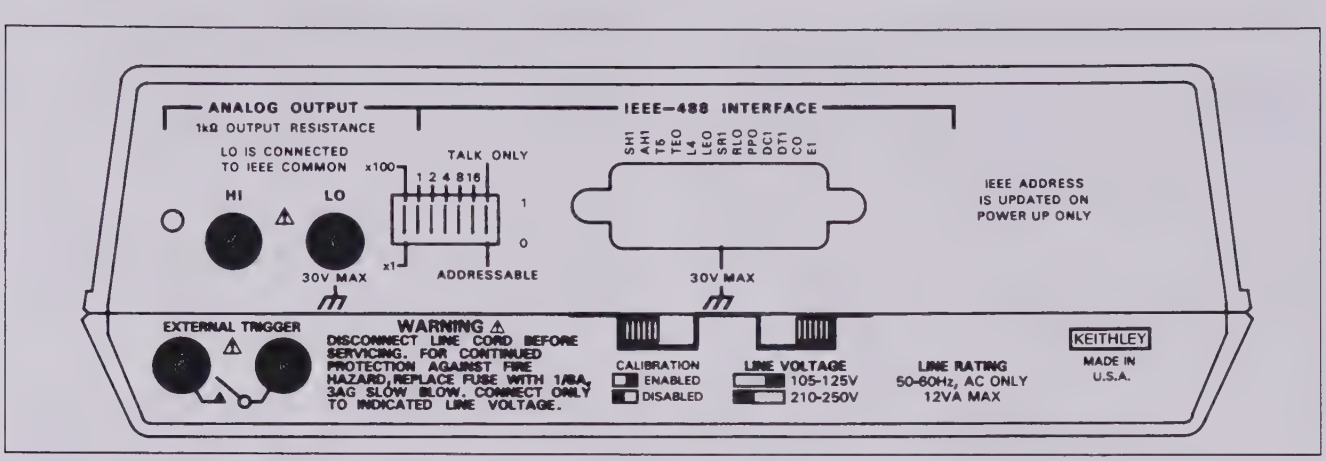


Figure 3-5. Rear Panel of Model 580 Showing IEEE-488 Connections and Switches

Table 3-1. IEEE-488 Contact Designations

Contact Number	IEEE-488 Desgination	Type
1	DIO1	Data
2	DIO2	Data
3	DIO3	Data
4	DIO4	Data
5	EOI (24)*	Management
6	DAV	Handshake
7	NRFD	Handshake
8	NDAC	Handshake
9	IFC	Management
10	SRQ	Management
11	ATN	Management
12	SHIELD	Ground
13	DIO5	Data
14	DIO6	Data
15	DIO7	Data
16	DIO8	Data
17	REN (24)*	Management
18	Gnd, (6)*	Ground
19	Gnd, (7)*	Ground
20	Gnd, (8)*	Ground
21	Gnd, (9)*	Ground
22	Gnd, (10)*	Ground
23	Gnd, (11)*	Ground
24	Gnd, LOGIC	Ground

*Numbers in parenthesis refer to signal ground return of reference contact number. EOI and REN signal lines return on contact 24.

WARNING

The voltage between IEEE-488 common and chassis ground must not exceed 30V or damage to the instrument may occur.

A typical signal line bus driver is shown in Figure 3-6. With the configuration shown, the driver has bidirectional capability. When the I/O control line is high, the line is configured as an output line. When the control line is low, the driver is set up for input operation. Note that not all signal lines have bidirectional capability. Some lines, such as ATN, will always be configured as an output line in the controller and as an input line for all other devices on the bus.

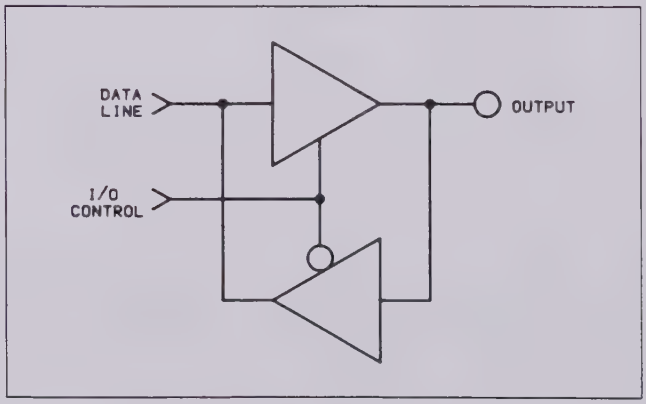


Figure 3-6. Typical IEEE-488 Bus Drive (one of 16)

3.2.3 Primary Address Selection

The Model 5802 must receive a listen command before it will respond to addressed commands. Similarly, the instrument must receive a talk command before it will transmit its data string, status word or status byte. These listen and talk commands are derived from the instrument's primary address. The Model 5802 is shipped from the factory with a primary address of 25 (11001). The primary address may be reset to any value between 0 and 30 as long as address conflicts with other bus instruments are avoided. This may be done by placing the primary address switches, which are shown in Figure 3-7, in the desired position. Note that the primary address of the instrument must agree with the address specified in the controller's programming language.

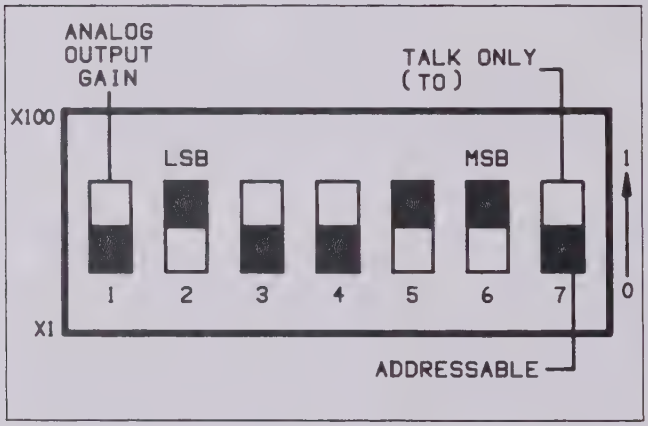


Figure 3-7. Primary Address Switch (Address 25 Shown)

NOTE

The primary address switch positions are read only upon power up. If the address is changed, the Model 580 must be turned off and then powered up again before the new address can be used.

Figure 3-7 shows the correct positions for the Model 5802 factory set value of 25 (11001). If a different address is required, the primary address may be changed as outlined in Table 3-2.

Table 3-2. Primary Address Switch Positions

Primary Address	MSB 5	4	3	2	LSB 1
0	0	0	0	0	0
1	0	0	0	0	1
2	0	0	0	1	0
3	0	0	0	1	1
4	0	0	1	0	0
5	0	0	1	0	1
6	0	0	1	1	0
7	0	0	1	1	1
8	0	1	0	0	0
9	0	1	0	0	1
10	0	1	0	1	0
11	0	1	0	1	1
12	0	1	1	0	0
13	0	1	1	0	1
14	0	1	1	1	0
15	0	1	1	1	1
16	1	0	0	0	0
17	1	0	0	0	1
18	1	0	0	1	0
19	1	0	0	1	1
20	1	0	1	0	0
21	1	0	1	0	1
22	1	0	1	1	0
23	1	0	1	1	1
24	1	1	0	0	0
25	1	1	0	0	1
26	1	1	0	1	0
27	1	1	0	1	1
28	1	1	1	0	0
29	1	1	1	0	1
30	1	1	1	1	0

NOTE

If other instrumentation is also connected to the bus, be sure that each device has a different primary address. If this precaution is not observed, erratic bus operation will result.

The primary address switches are binary weighted; A1 is the least significant bit, A5 is the most significant bit. For example, the binary value for the factory set primary address of 25 is 11001. Use the tip of a pencil to operate the switches.

NOTE: Instruments should not be operated with a primary address of 31 (11111) even though it is possible to set the Model 5802 address to those positions. This address is reserved for the UNT and UNL commands; erratic operation may result if primary address 31 is used.

3.3 SOFTWARE CONSIDERATIONS

The necessary handler routines to operate the IEEE-488 bus are described in this section.

3.3.1 Controller Interface Routines

Before a controller can be used with the IEEE-488 interface, make certain that appropriate handler software is present within the controller. The HP-85 interface card for the HP-85 computer, for example, must be used with an additional I/O ROM, which contains the necessary handler software.

Other small computers used as controllers have limited IEEE-488 command capability. The PET/CBM computers are incapable of sending multiline commands from BASIC, although these commands can be sent through machine language routines. Other small computers' capabilities depend on the particular interface being used. Often, little software "tricks" are required to achieve desired results.

Make sure the proper software is being used with the interface. Often, the user may suspect that hardware is causing a problem when it is actually the software causing the problem.

3.3.2 HP-85 BASIC Statements

Many of the programming instructions covered in Section 4 use examples written in Hewlett Packard Model 85 BASIC. The HP-85 was chosen for these examples because it has a large number of BASIC statements that control IEEE-488 operation. This selection covers those HP-85 BASIC statements essential to Model 580/5802 operation.

A list of HP-85 BASIC statements is shown in Table 3-3. All statements have a one or three digit argument that must be specified. The first digit is the HP-85 interface select code which is set to 7 at the factory. The last two digits of those statements that require a three digit argument specify primary address. Generally, only those commands that require an address to be sent over the bus require that the primary address be specified in the BASIC statement.

Table 3-3. HP-85 IEEE-488 BASIC Statement

Statement	Action	Bus Command Sequence
ABORTIO 7	Send IFC.	IFC
CLEAR 7	Send DCL.	ATN•DCL
CLEAR 725	Send SDC to device 25.	ATN•UNL;MTA;LAG;SDC
ENTER 725;A$	Device 25 addressed to talk. Data placed in A$.	ATN•UNL;MLA;TAG;$\overline{ATN}$;data
LOCAL 725	Send GTL to device 25.	ATN•UNL;MTA;LAG;GTL
OUTPUT 725;A$	Device 25 addressed to listen. Transmit A$.	ATN•MTA;UNL;LAG;$\overline{ATN}$;data
REMOTE 7	Set REN true.	REN
REMOTE 725	Send REN true. Address device 25 to listen.	REN;ATN•UNL;MTA;LAG
RESET 7	Send IFC, cancel REN.	IFC;REN;$\overline{REN}$
SPOLL(725)	Address device 25 to talk. Conduct serial poll.	ATN•UNL;MLA;TAG;SPE;$\overline{ATN}$; status byte;ATN•SPD;UNT
TRIGGER 7	Send GET	ATN•GET
TRIGGER 725	Address device 25 to listen. Send GET.	ATN•UNL;MTA;LAG;GET

Those statements in the table with three digit arguments assume that the primary address of the device is set at 25. Other primary addresses require that the last two digits be set to the corresponding value. For example, to send a GTL command to device 25, the following BASIC statement would be used.

```
LOCAL 725
```

Some of the statements in the table have two forms; the exact configuration used depends on the desired command. For example, CLEAR 7 will cause a DCL to be sent to all devices on the bus, while CLEAR 725 causes an SDC to be transmitted to device 25.

The third column of Table 3-3 lists command sequence mnemonics. While most of these are covered elsewhere, a couple of points should be noted. The ATN line is set low by the controller if the data bus contains a multiline command. This is indicated in the table by ANDing the ATN mnemonic with the first command on the bus. For example, ATN GET means that ATN and GET are sent simultaneously. Two commands not previously covered are MTA (My Talk Address) and MLA (My Listen Address). These are ordinary PCG (Primary Command Group) addresses sent by the HP-85 to facilitate bus operation in certain circumstances.

NOTE

The HP-85 address is set to 21 at the factory. Since each device on the bus must have a unique primary address, do not set the Model 5802 to the controller's address.

3.3.3 Interface Function Codes

The interface function codes are part of the IEEE-488-1978 standards. These codes define an instrument's ability to support various functions and should not be confused with programming commands found elsewhere in this manual.

Table 3-4. lists the codes for the Model 5802. These codes are also listed for convenience on the rear panel of the instrument immediately above the IEEE-488 connector. The numeric value following each one or two letter code defines Model 5802 capabilities as follows:

Table 3-4. Interface Function Codes

Code	Interface Function
SH1	Source Handshake Capability
AH1	Acceptor Handshake Capability
T5	Talker (Basic Talker, Serial Poll, Talk Only Mode, Unaddressed To Talk On LAG)
L4	Listener (Basic Listener, Unaddressed To Listen On TAG)
SR1	Service Request Capability
RL0	No Capability
PP0	No Parallel Poll Capability
DC1	Device Clear Capability
DT1	Device Trigger Capability
C0	No Controller Capability
E1	Open Collector Bus Driver
TE0	No Extended Talker Capability
LE0	No Extended Listener Capability

SH (Source Handshake Function)—The ability of the Model 5802 to initiate message/data transfer on the data bus is provided by SH function.

AH (Acceptor Handshake Function)—Guaranteed proper reception of message data on the data bus is provided by the AH function.

T (Talker Function)—The ability of the Model 5802 to send device-dependent data over the bus (to other devices) is provided by the T function. Model 5802 talker capability exists after the instrument has been addressed to talk.

L (Listener Function)—The ability of the Model 5802 to receive device-dependent data over the bus (from other devices) is provided by the L function. Listener function capability of the Model 5802 exists only after the instrument has been addressed to listen.

SR (Service Request Function)—The ability of the Model 5802 to request service from the controller is provided by the SR function.

RL (Remote Local Function)—The ability of the Model 5802 to be placed in the remote or local modes is provided by the RL function.

PP (Parallel Poll Function)—The Model 5802 does not have parallel polling capabilities.

DC (Device Clear Function)—The ability of the Model 5802 to be cleared (initialized) is provided by the DC function.

DT (Device Trigger Function)—The ability for the Model 5802 to have its basic operation started is provided by the DT function.

C (Controller Function)—The Model 5802 does not have controller capabilities.

TE (Extended Talker Capability)—The Model 5802 does not have extended talker capability.

LE (Extended Listener Capability)—The Model 5802 does not have extended listener capability.

3.3.4 Interface Commands

Interface commands controlling Model 580/5802 operation are listed in Table 3-5. Not included in the table are device-dependent commands, which are covered in detail in Section 4.

Table 3-5. IEEE-488 Command Groups

HANDSHAKE COMMAND GROUP
DAC=DATA ACCEPTED
RFD=READY FOR DATA
DAV=DATA VALID

UNIVERSAL COMMAND GROUP
ATN=ATTENTION
DCL=DEVICE CLEAR
IFC=INTERFACE CLEAR
LLO=LOCAL LOCKOUT
REN=REMOTE ENABLE
SPD=SERIAL POLL DISABLE
SPE=SERIAL POLL ENABLE

ADDRESS COMMAND GROUP
LISTEN: LAG=LISTEN ADDRESS GROUP
MLA=MY LISTEN ADDRESS
UNL=UNLISTEN
TALK: TAG=TALK ADDRESS GROUP
MTA=MY TALK ADDRESS
UNT=UNTALK
OTA=OTHER TALK ADDRESS

ADDRESSED COMMAND GROUP
ACG=ADDRESSED COMMAND GROUP
GET=GROUP EXECUTE TRIGGER
GTL=GO TO LOCAL
SDC=SELECTIVE DEVICE CLEAR

STATUS COMMAND GROUP
RQS=REQUEST SERVICE
SRQ=SERIAL POLL REQUEST
STB=STATUS BYTE
EOI=END

SECTION 4
OPERATION

4.1 INTRODUCTION

The Model 5802 is an IEEE-488 interface for the Model 580 Micro-ohmmeter. Since all IEEE-488 operation is done through commands given over the bus, IEEE-488 operation precludes the use of operating controls in the usual sense. Instead, all operating functions are controlled by programming.

This section describes important programming functions in detail. Included are: general bus commands, device-dependent commands, status word and status byte, and other important information. The information presented in this manual assumes that the operator is familiar with all normal aspects of Model 580 operation. For information on front panel operation, refer to the Model 580 Operator's Manual.

NOTE

Programming examples in this section assume that the Model 5802 primary address is set to 25. Those examples with addressed commands will not function unless the primary address of the instrument is set to that value. Refer to Section 3 for information on setting the primary address.

4.2 GENERAL BUS COMMANDS

General bus commands are those commands which have the same general meaning regardless of instrument configuration. These commands are grouped into two categories:

Addressed Commands—These commands require that the primary address of the instrument agrees with the primary address in the controller's language.

Unaddressed Commands—No primary address is required for these commands. All devices equipped to implement these commands will do so simultaneously when the command is sent.

General bus commands are summarized in Table 4-1, which also lists the HP-85 BASIC statement that sends each command. Each addressed command statement assumes a primary address of 25 (11001).

Table 4-1. General Bus Commands

Command	Addressing Required?	HP-85 BASIC Statement
REN	Yes	REMOTE 725
IFC	No	ABORTIO 7
GTL	Yes	LOCAL 725
DCL	No	CLEAR 7
SDC	Yes	CLEAR 725
GET*	Yes	TRIGGER 725
GET*	No	TRIGGER 7

*GET may be sent with or without addressing.

4.2.1 REN (Remote Enable)

The remote enable command is sent to the Model 5802 by the controller to set the instrument up for remote operation. Generally, this should be done before attempting to program the instrument over the bus. The Model 580/5802 indicates that it is in the remote mode by turning on the front panel RMT annunciator.

To place the Model 580/5802 in the remote mode, the controller must perform the following steps:

1. Set the REN line true.
2. Address the Model 580/5802 to listen.

NOTE

Setting the REN true without addressing will not cause the REMOTE indicator to turn on; however, once the REN is true, the REMOTE indicator turns on the next time an addressed command is received.

Programming Example—This sequence is automatically sent by the HP-85 when the following is typed into the keyboard.

```
REMOTE 725
```

After the END LINE key is pressed, the Model 580 REMOTE annunciator (RMT) should turn on. If not, check to see that the instrument is set for the proper primary address. Also check to see that all the bus connections are tight.

4.2.2 IFC (Interface Clear)

The IFC command is sent by the controller to set the Model 580/5802 to the talk and listen idle states.

To send the IFC command, the controller need only set the IFC line true.

Programming Example—Before demonstrating the IFC command, turn on the front panel remote (RMT) annunciator by entering the following statement into the HP-85 computer:

```
REMOTE 725
```

The front panel remote (RMT) annunciator should now be on. The IFC command can now be sent by typing in the following statement:

```
ABORTIO 7
```

After the END LINE key is pressed, the Model 580/5802 is in the talk idle state. Note that the remote mode is not cancelled.

4.2.3 GTL (Go To Local)

The GTL command is used to take the instrument out of the remote mode. To send the GTL command, the controller must perform the following sequence:

1. Set ATN true.
2. Address the Model 580/5802 to listen.
3. Place the GTL command on the bus.

Programming Example—If the instrument is not in the remote mode, enter the following statements into the HP-85 computer:

```
REMOTE 725
```

Check to see that the RMT annunciator is on. The GTL command sequence is automatically sent by the HP-85 with the following statement:

```
LOCAL 725
```

Note that the remote (RMT) annunciator on the front panel turns off.

NOTE

Setting the REN line false with the LOCAL 7 statement will also take the instrument out of the remote mode.

4.2.4 LLO (Local Lockout)

The LLO command may be used to "lock out" front panel button control on the Model 580. Note that all devices on the bus equipped to respond to a LLO command will do so simultaneously. When the Model 580/5802 receives a LLO command, the instrument will no longer respond to front panel buttons, but can still be controlled over the bus by the controller.

Programming Example—To put the instrument into local lockout, enter the following statement into the HP-85 controller:

```
REMOTE 725
LOCAL LOCKOUT 7
```

Note that the RMT and LLO annunciators come on.

To get out of local lockout and remote, type:

```
LOCAL 7
```

Both annunciators turn off.

To stay in local lockout but get out of remote (go to LOCAL), type:

```
LOCAL 725
```

Note that the RMT annunciator turns off, but LLO stays on.

4.2.5 DCL (Device Clear)

The DCL command may be used to clear the Model 580, setting it to a known state. Note that all devices on the bus equipped to respond to a DCL will do so simultaneously. When the Model 580/5802 receives a DCL command, it will return to the default conditions listed in Table 4-2.

To send a DCL command, the controller must perform the following steps:

1. Set ATN true.
2. Place the DCL command on the bus.

Programming Example—Using the front panel controls, select POLARITY and the 20Ω range. Type in the following statement into the HP-85 computer:

```
REMOTE 725
CLEAR 7
```

When the END LINE key is pressed after the CLEAR 7 statement, the instrument returns to the default conditions listed in Table 4-2 (the POLARITY will return to its positive power up condition).

4.2.6 SDC (Selective Device Clear)

The SDC command performs the same function as the DCL command except that only the addressed device responds. This command is useful for clearing only a selected instrument instead of all instruments at once. The Model 580 returns to the default conditions listed in Table 4-2 when responding to a DCL command.

To transmit the SDC command, the controller must perform the following steps:

1. Set ATN true.
2. Address the Model 5802 to listen.
3. Place the SDC command on the bus.

Programming Example—Using front panel controls select DC drive. Enter the following statements into the HP-85 computer:

```
REMOTE 725
CLEAR 705
```

Note that the instrument did not respond to the SDC because the command was sent with a primary address of five. Now enter the following statement into the HP-85:

```
CLEAR 725
```

This time, the instrument returns to the default conditions listed in Table 4-2 (pulsed drive).

4.2.7 Serial Polling (SPE, SPD)

The serial polling sequence is used to obtain the Model 580/5802 status byte. Usually, the serial polling sequence is used to determine which of several devices has requested service over the SRQ line. However, the serial polling sequence may be used at any time to obtain the status byte from the Model 580/5802. For more information on status byte format, refer to Paragraph 4.3.11.

The serial polling sequence is conducted as follows:

1. The controller sets the ATN line true.
2. The SPE (Serial Poll Enable) command is placed on the bus by the controller.
3. The Model 580/5802 is addressed to talk.
4. The controller sets ATN false.
5. The instrument then places its status byte on the bus to be read by the controller.
6. The controller sets the ATN line true and places the SPD (Serial Poll Disable) on the bus to end the serial polling sequence.

Steps 3 through 5 may be repeated for other instruments on the bus by using the correct talk address for each instrument. ATN must be true when the talk address is transmitted and false when the status byte is read.

Programming Example—The HP-85 SPOLL statement automatically performs the serial polling sequence. To demonstrate serial polling, momentarily power down the instrument and power it up again. Enter the following statement into the HP-85 computer:

```
REMOTE 725
S=SPOLL (725)
DISP S
```

When the END LINE key is pressed after the S=SPOLL statement, the computer performs the serial polling sequence. When the END LINE key is pressed after the DISP S statement, the status byte value (0) is displayed on the CRT. The status byte has a value of 0 with this example because no bits in the byte are set. Paragraph 4.3.11 covers the status byte format in detail.

Table 4-2. Default Values (Status Upon Power Up or After SDC or DCL)

Mode	Value	Status
Range	—	Reflects front panel selection
Operate	—	Reflects front panel selection
Dry Circuit Test	—	Reflects front panel selection
Relative	Z0	Off
Calibration	—	Off
Polarity	P0	Positive
Drive	D0	Pulsed current
Trigger	T0	Continuous on TALK
EOI	K0	EOI is transmitted on the last byte out
SRQ	M0	No SRQ
Alternate Output	—	Standard output
Prefix	G0	Send Prefix
Terminator	Y(CR)(LF)	Carriage Return, Line Feed

4.3 DEVICE-DEPENDENT COMMAND PROGRAMMING

IEEE-488 device-dependent commands are sent to the Model 580/5802 to control its various operating modes. Each command is made up of an ASCII alpha character followed by one or more numbers designating specific parameters. For example, REL is programmed by sending an ASCII "Z" followed by a zero or one for turning it off or on. The IEEE-488 bus treats device-dependent commands as data in that ATN is high when the commands are transmitted.

A number of commands may be grouped together in one string. A command string is terminated by an ASCII "X" which tells the instrument to execute the command string.

If an illegal command or command parameter is present within a command string the instrument will:

1. Ignore the entire command string.
2. Set appropriate error bits in the status byte.
3. Generate an SRQ if programmed to do so.

These programming aspects are covered in paragraph 4.3.11. HP-85 examples are included throughout this section to clarify programming.

NOTE

Before starting a programming example, it is recommended that the instrument be set to its default values by sending a DCL over the bus. See paragraph 4.2.5 for information on using the SDC command.

If the HP-85 should become "hung up" at any point (due to inadvertent command errors, etc.), operation may be restored by holding down the SHIFT key and then pressing RESET on the keyboard.

In order to send a device-dependent command, the controller must perform the following sequence:

1. Set ATN true.
2. Set the REN line true.
3. Address the Model 580/5802 to listen.
4. Set ATN false.
5. Send the command string over the bus one byte at a time.

Programming Example—Device-dependent commands are sent by the HP-85 using the following statement:

```
OUTPUT 725;A$
```

A$ in this case contains the ASCII characters that form the command string.

NOTE

REN must be true when attempting to program the Model 580. If REN is false, the RMT annunciator will be off.

Commands that affect the Model 580 are listed in Table 4-3. All the commands listed in Table 4-3 are covered in detail in the following paragraphs.

NOTE

The programming examples that follow assume that the Model 580/5802 primary address is at its factory setting of 25 (11001).

Table 4-3. Device-Dependent Command Summary

Mode	Command	Description
Execute	X	Implement all DDCs when an X is received.
Ranges		**Non Dry Circuit Test** / **Dry Circuit Test**
	R0	Auto / Auto
	R1	200m / 200m
	R2	2 / 2
	R3	20 / 20
	R4	200 / 20
	R5	2 k / 20
	R6	20 k / 20
	R7	200 k / 20
Operate	O0	Standby
	O1	Operate
Dry Circuit Test	C0	Non Dry Circuit Test
	C1	Dry Circuit Test
Relative	Z0	REL off
	Z1	REL on
Calibration Point	V+n.nnnnE+nn	Enter calibration. Calibration point equal to the input resistance.
Store Calibration Constants	L0	Store calibration constants and exit calibration.
Polarity	P0	Pol+
	P1	Pol–
Drive	D0	Pulsed Drive
	D1	DC Drive
Trigger Modes	T0	Continuous on Talk
	T1	One-shot on Talk
	T2	Continuous on GET
	T3	One-shot on GET
	T4	Continuous on "X"
	T5	One-shot on "X"
EOI	K0	EOI is transmitted on the last byte out.
	K1	EOI is not transmitted.
SRQ	Mnnn	nnn = 0 to 255 base 10 N/A = Bit ignored
	Bits:	**Data** / **Error**
	MSB 7	N/A / N/A
	6	SRQ / SRQ
	5	NORMAL=0 / ERROR=1
	4	BUSY / N/A
	3	READING DONE / N/A
	2	N/A / NOT IN REMOTE
	1	N/A / IDDC
	LSB 0	READING OVERFLOW / IDDCO
Output Alternate String on Talk	U0	Output the status word on the next reading.
Prefix (Data Format)	G0	Send prefix.
	G1	Do not send prefix.
Install IEEE-488 Terminator Character	Y(ASCII)	ASCII character
	Y(LF)	(CR)(LF)
	Y(CR)	(LF)(CR)
	Y(DEL)	No terminator

4.3.1 Execute (X)

The execute command is implemented by sending an ASCII "X" over the bus. Its purpose is to tell the Model 580/5802 to execute the other device-dependent commands. Generally, the "X" character is the last byte in the command string. Also, "X" triggers the instrument in T4 and T5.

NOTE

Command strings sent without an "X" character will not be executed at that time. They will be stored in the command buffer. The next time an "X" character is received, the stored commands are executed assuming all commands in the previous string were valid.

Programming Example—From the front panel, make polarity positive. Then, enter the following example into the HP-85 computer:

```
REMOTE 725
OUTPUT 725;''P1X''
```

Polarity is now negative, which indicates that the instrument received the command.

4.3.2 Range (R)

Ranges are programmable over the bus. The range commands can be found in Table 4-4. Upon power up, or after receiving a DCL or SDC, the range of the Model 580 corresponds to the range pushbutton selected.

Programming Example—Cycle power on the Model 580 and manually select the 2Ω range. Enter the following statements into the HP-85:

```
REMOTE 725
OUTPUT 725;''R3X''
```

When the END LINE is pressed the second time, the instrument switches to the R3 range (20Ω).

Table 4-4. Range Commands

Range Command	Description	
	Non Dry Circuit Test	Dry Circuit Test
R0	Auto	Auto
R1	200m	200m
R2	2	2
R3	20	20
R4	200	20
R5	2 k	20
R6	20 k	20
R7	200 k	20

4.3.3 Operate/Standby (O)

With the use of the O command, the Model 580 can be put in either operate (ready to take readings) or standby by the controller.

O0 = Standby
O1 = Operate

Upon power up, or after a DCL or SDC command, the status of the O command reflects the front panel button selection.

Programming Example—Model 580 is put into standby with the following HP-85 statement sequence:

```
REMOTE 725
OUTPUT 725;''O1X''
```

The instrument is now in standby.

4.3.4 Dry Circuit Test (C)

The status of the Dry Circuit Test function of the Model 580 on power up reflects the front panel button selection. If Dry Circuit Test is chosen with a range higher than 20Ω, "Err" will appear on the instrument display, and the ohms and DRY CIRCUIT TEST annunciators will flash.

C0 = Non Dry Circuit Test
C1 = Dry Circuit Test

Programming Example—Model 580 is put into Dry Circuit Test with the following HP-85 statement sequence:

```
REMOTE 725
OUTPUT 725;"C1X"
```

The instrument is now ready to take dry circuit test measurements; the DRY CIRCUIT TEST annunciator appears on the Model 580 display.

4.3.5 Relative (Z)

REL serves as a means for a baseline suppression. When the correct REL command is sent over the bus, the instrument will enter REL, as shown by the REL annunciator. All readings displayed or sent over the bus while REL is enabled are the differences between the stored baseline and the actual resistance level. For example, if a 100mΩ baseline is stored, 100mΩ will be subtracted from all subsequent readings as long as REL is enabled. The value of the stored baseline can be as little as a few micro-ohms or as large as the selected range will permit. REL is controlled by sending one of the following commands over the bus.

Z0 = REL Disabled
Z1 = REL Enabled

Upon power-up, or after DCL or SDC, Z0 is selected.

Programming Example—With the front panel REL button, disable REL and enter the following statements into the HP-85 keyboard:

```
REMOTE 725
OUTPUT 725;"Z1X"
```

After the END LINE key is pressed the second time, the REL annunciator will turn on.

NOTE
See the Model 580 Instruction Manual for detailed information on the use of REL.

4.3.6 Digital Calibration (V) and Storage (L)

Calibration over the IEEE-488 bus can only be accomplished with the calibration switch in the ENABLED position. Refer to the Model 580 Service Manual for complete information.

Through the use of the V command, the Model 580 enters calibration and the calibration value is transmitted to the instrument. The calibration command is in the form:

V±n.nnnnE±nn

where: ±n.nnnn represents the mantissa (4½ digits)
E±nn represents the exponent

Through the use of the L0 command the calibration values entered are stored in NVRAM, then the Model 580 is returned to normal operation.

NOTES:

1. Only as many significant digits as necessary need to be entered. For example, for calibration of the 20Ω range with a 19.0000 input value, the following command would be used:

```
V19X
```

2. The correct calibration value must be connected to the instrument before the V command is sent.

Programming Example—

CAUTION
If the calibration switch is in the ENABLED position (refer to the maintenance section of the Model 580 Service Manual), DO NOT PERFORM THESE STEPS UNLESS A CHANGE IN CALIBRATION IS DESIRED. Unless proper calibration parameters have been previously programmed, inadvertently using this command seriously affects instrument accuracy.

Using front panel controls, place the instrument in the 2Ω range. Connect a precise 1.9Ω calibration resistor to the Model 580 test leads and enter the following statements into the HP-85 computer:

```
REMOTE 725
OUTPUT 725;''V1.9X''
OUTPUT 725;''L0X''
```

When the END LINE key is pressed after the V1.9X statement, the instrument calibrates itself in accordance with the applied signal.

When the END LINE key is pressed after the L0X statement, permanent storage takes place.

4.3.7 Polarity (P)

The Model 580 provides a selectable positive or negative SOURCE current. The red SOURCE terminal is positive for P0 and negative for P1.

P0=Positive
P1=Negative

Upon power up, or after a DCL or SDC command, the P0 (positive) is enabled.

Programming Example—Enter the following commands into the HP-85 follows:

```
REMOTE 725
OUTPUT 725; ''P1X''
```

The SOURCE current is now negative.

4.3.8 Drive (D)

The DRIVE feature of the Model 580 allows the user to measure an unknown with a DC or pulsed source.

D0 = Pulsed drive
D1 = DC drive

Upon power up, or after the instrument receives a DCL or SDC command, the D0 or pulsed source is enabled.

Programming Example—DRIVE can be entered or changed with the following HP-85 statement sequence:

```
REMOTE 725
OUTPUT 725; ''D1X''
```

After END LINE is pressed the second time, the instrument will be placed in DC (⎓).

4.3.9 Triggering (T)

Triggering provides a stimulus to begin a reading conversion within the instrument. Triggering may be done in two ways: in continuous, a single trigger command is used to start a continuous series of readings; in one-shot, a separate trigger stimulus is required to start each conversion. The Model 580 has six trigger commands as follows:

T0 Continuous On Talk
T1 One-Shot On Talk
T2 Continuous On GET
T3 One-Shot On GET
T4 Continuous On X
T5 One-Shot On X

Upon power-up or after a DCL or SDC command, T0 is enabled. In T0 and T1, triggering is done by addressing the Model 580 to talk. In T2 and T3, a GET command provides the trigger stimulus. In T4 and T5, the execute (X) character triggers the instrument.

Programming Example—Place the instrument in one-shot talk with the following HP-85 statement sequence:

```
REMOTE 725
OUTPUT 725;''T1X''
```

After the END LINE key is pressed the second time, the instrument will be in one-shot on talk. The instrument is waiting for a trigger.

Trigger the instrument with a talk command by entering the following statement into the HP-85:

```
ENTER 725;A$
```

After pressing END LINE one reading will be processed. To continue taking readings, one talk command must be sent for each conversion.

4.3.10 EOI (K)

The EOI line on the bus is usually set low by a device during the last byte of its data transfer sequence. The last byte

is properly identified, which allows variable length data words to be transmitted. The Model 580 normally sends EOI during the last byte of its data string or status word. The EOI response of the instrument may be sent with one of the following commands:

K0 = Send EOI during last byte.
K1 = Send no EOI.

K0 is assumed at power up.

Programming Example—Model 580 EOI response is suppressed with the following HP-85 statement sequence:

```
REMOTE 725
OUTPUT 725;"K1X"
```

Note that the HP-85 does not normally rely on EOI to mark the last byte of data transfer. Some controllers, however, may require that EOI be present at the end of the transmitted string.

4.3.11 SRQ (M) and Status Byte Format

The SRQ command code controls the number of conditions within the Model 580 which cause the instrument to request service from the controller with the SRQ command. Once the SRQ is generated, the Model 580 status byte can be checked to determine if it was the Model 580 that requested service. Other bits in the status cycle could also be set depending on certain data or error conditions.

The Model 580 can be programmed to generate an SRQ under one or more of the following conditions:

1. If a reading has been completed.
2. If an overflow condition occurs.
3. If a busy condition occurs.
4. If an Illegal Device-Dependent Command Option (IDDCO) is received.
5. If an Illegal Device-Dependent Command (IDDC) is received.
6. If the instrument is not in remote when a command is received.

Upon power up or after a DCL or SDC command, SRQ is disabled.

SRQ Mask—In order to facilitate SRQ programming, the Model 580 uses an internal mask to generate an SRQ. When a particular mask bit is set, the Model 580 sends an SRQ when those conditions occur. Bits within the mask can be controlled by sending the ASCII letter "M" followed by a decimal number to set the appropriate bits. Table 4-5 lists the commands to set the various mask bits, while Figure 4-1 shows the general mask format.

Table 4-5. SRQ Mask Commands

Command	Status Bits Enabled	Conditions to Generate SRQ
M0	—	Clear SRQ Data Mask
M1	B0	Reading Oveflow
M8	B3	Reading Done
M9	B3, B0	Reading Done or Reading Overflow
M16	B4	Busy
M17	B4, B0	Busy or Reading Overflow
M24	B4, B3	Busy or Reading Done
M25	B4, B3, B0	Busy, Reading Done or Reading Overflow
M32	B5	Clear SRQ Error Mask
M33	B5, B0	IDDCO
M34	B5, B1	IDDC
M35	B5, B1, B0	IDDC or IDDCO
M36	B5, B2	Not in Remote
M37	B5, B2, B0	Not in Remote or IDDCO
M38	B5, B2, B1	Not in Remote or IDDC
M39	B5, B2, B1, B0	Not in Remote, IDDC or IDDCO

Programming Example—Cycle power on the Model 580 and program it for SRQ on IDDCO and output the status word.

PROGRAM	COMMENTS
`10 REMOTE 725`	Set up for remote operation.
`20 OUTPUT 725; ''M33X''`	Program for SRQ on IDDCO.
`30 OUTPUT 725; ''U0X''`	Send status command.
`35 DISP''***DPCORZKTM DMEHY''`	
`40 ENTER 725; A$`	Enter commands into the computer.
`50 DISP A$`	Display on CRT.
`60 END`	

After entering the program, press the HP-85 RUN key. The U0 status word will then be displayed. The Me bytes (refer to Figure 4-2) contain "01" indicating that the Model 580 is programmed to SRQ on an IDDCO.

Status Byte Format—The status byte contains information relating to data and error conditions within the instrument. When a particular bit is set, certain conditions are present. Table 4-6 lists the meanings of the various bits and Figure 4-1 shows the general format of the status byte, which is obtained by using the SPE, SPD polling sequence described in paragraph 4.2.6.

Table 4-6. Status Byte and Mask Interpretation

Bit	Bit 5 = 0 (Data Conditions)	Bit 5 = 1 (Error Conditions)
0 (LSB)	Overflow	IDDCO
1	N/A	IDDC
2	N/A	No remote
3	Reading done	N/A
4	Busy	N/A
5	Data	Error
6	SRQ	SRQ
7	N/A	N/A

If the status byte is read when no SRQ was generated by the Model 580 (bit 6 is clear), the current status of the instrument will be read. For example, if a reading was done, bit 3 would be set.

When an SRQ is generated by the Model 580, bit 6 of the status byte will be set. If an SRQ was caused by an error condition, bit 5 will also be set along with one of the error conditions (B0, B1 or B2). Only the error that caused the initial SRQ will be defined by the status byte.

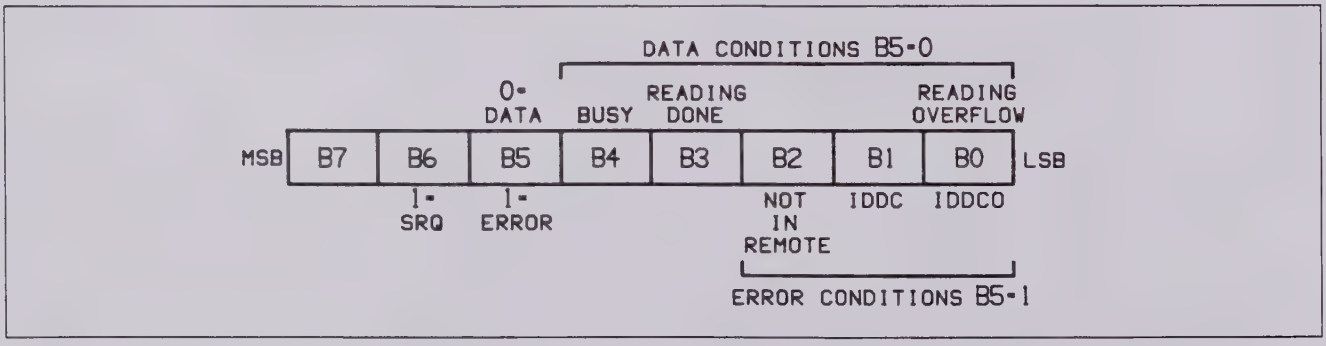


Figure 4-1. Status Byte Format

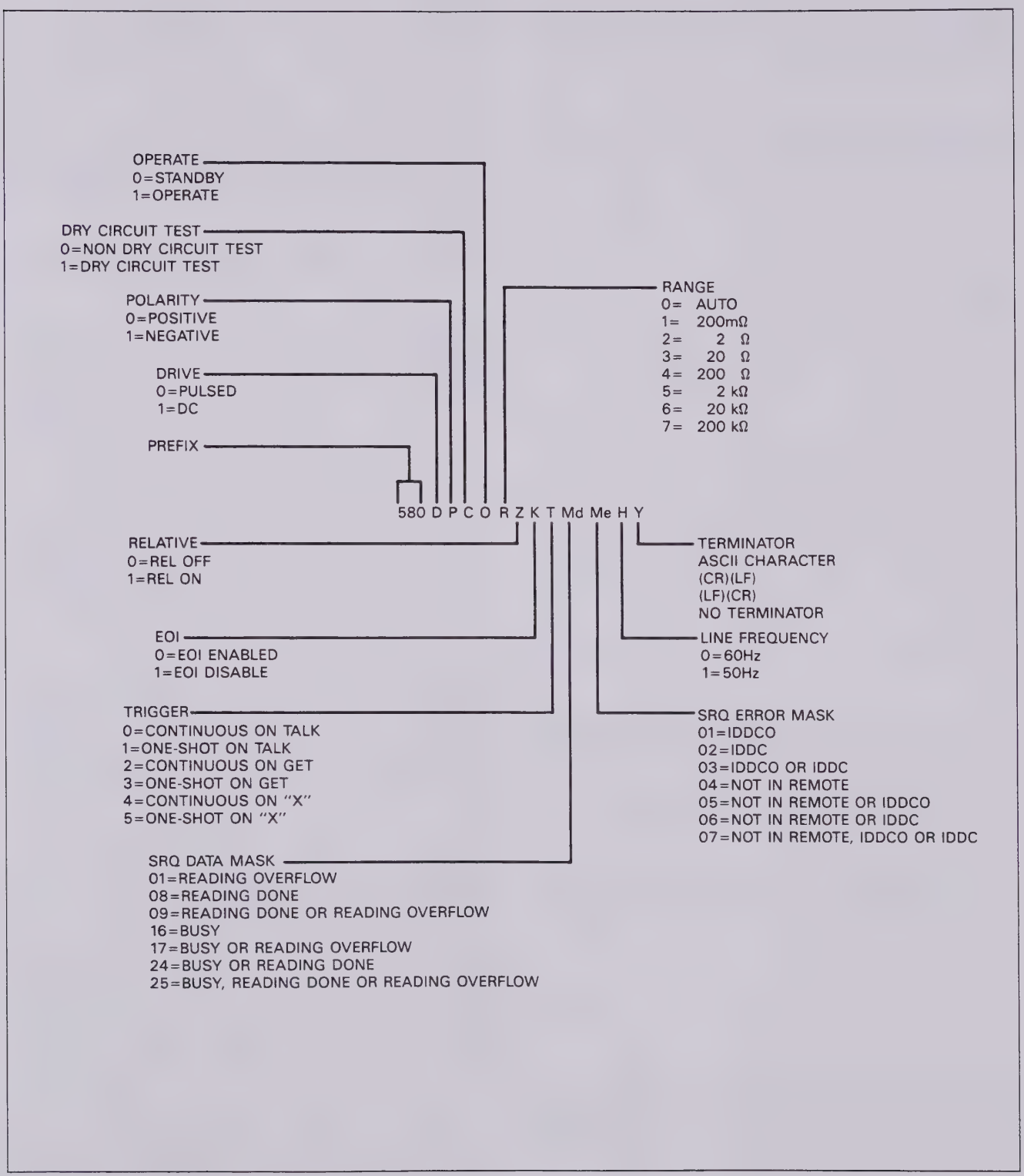


Figure 4-2. General Format for U0 Command

If the SRQ was caused by a data condition, bit 5 will be clear and the appropriate data condition bits (B0, B3 and B4) will be set. If a busy condition caused the SRQ, then only the busy bit will be set.

After an SRQ, the status byte will remain unchanged until it is read. The various bits in the status byte are described below:

Reading Overflow—Set when an overrange input is applied to the instrument.

Reading Done—Set when the instrument has completed the present conversion.

Busy—The instrument is still executing a prior command and is not ready to accept a new command.

IDDCO—An illegal command option such as R9 has been received from the controller. This bit is cleared when the status byte is read.

IDDC—An illegal command, such as N1, has been received from the controller. The IDDC bit is cleared on a reading of the status byte.

Not in Remote—The Model 580 is in local when a DDC is received.

NOTES:

1. Once the Model 580 has generated an SRQ, its status byte must be read to clear the SRQ line. Otherwise the instrument continuously asserts SRQ.
2. The Model 580 may be programmed to generate an SRQ for more than one condition simultaneously.

Programming Example—Enter the following program into the HP-85 computer.

PROGRAM	COMMENTS
`10 REMOTE 725`	Set up for remote operation.
`20 OUTPUT 725;''M33X''`	Program for SRQ on IDDCO.
`30 OUTPUT 725;''R9X''`	Attempt to program illegal command option.
`40 S=SPOLL(725)`	Perform serial poll.
`50 DISP''B7 B6 B5 B4 B3 B2 B1 B0''`	
`60 FOR I=7 TO 0 STEP -1`	Loop eight times.
`70 DISP BIT(S,I)`	
`80 NEXT I`	
`90 DISP`	
`100 DISP''  v  v  v''`	
`110 DISP'' SRQ ERROR  IDDCO''`	
`120 DISP`	
`130 END`	

NOTE

To align the display properly, type in the program exactly as shown. In line 100 the space between the first quotation marks and the first pointer is four spaces. Then to the next pointer is two spaces, and 14 spaces to the last pointer in the line. In line 110 the space between the first quotation marks and SRQ is two spaces. Then to ERROR allow two spaces and then 10 spaces to IDDCO.

To run the program press the HP-85 RUN key. The computer conducts a serial poll and displays the status bits in order on the CRT. The SRQ (B6), error (B5) and IDDCO (B1) are set because line 30 of the program attempted to program the instrument with an illegal command option (R9).

After the program has been entered, press the HP-85 RUN key. Note the CRT, it will be as follows:

```
B7 B6 B5 B4 B3 B2 B1 B0
 0  1  1  0  0  0  1  0
    v  v              v
  SRQ  ERROR        IDDCO
```

Bit 6 (B6) is set, meaning a SRQ condition exists. Bit 5 (B5) is also set, meaning there is an error condition. Bit 1 is set, meaning an Illegal Device-Dependent Command Option (IDDCO) condition exists.

4.3.12 Status Word (U) or Alternate Output

The status word commands allow access to information concerning present operating modes of the instrument. When the status word command is given, the Model 580 transmits status information instead of its normal data string the next time it is addressed to talk. The Model 580 status word command is:

U0 = Send instrument status on operating modes.

Figure 4-2 shows the general format for the U0 command. The letters in the U0 format correspond to other device-dependent commands.

NOTES:

1. Status word information is returned only once each time the command is sent.
2. The returned terminator character (Y) is derived by ANDing the 00001111 and ORing the result with 00110000. For example, the last byte in the normal (CR LF) terminator sequence is an LF or ASCII 10 (00001010). ANDing with 00001111 yields 00111010 which is printed out as an ASCII colon (:).
3. The status word should not be confused with the status byte. The status word contains a number of bytes pertaining to the various operating modes of the instrument. The status byte is a single byte that is read with the SPE, SPD command sequence and contains information on SRQ status and error and data conditions.
4. The returned SRQ mode (M) value is determined by adding up the value of the bit positions in the status byte that could cause an SRQ according to the previous programmed value of the SRQ mode. Refer to paragraph 4.3.11 for complete information on the SRQ mask and status byte.
5. Line frequency (H) is 0 for 60Hz and 1 for 50Hz.

Programming Example—Enter the following program into the HP-85. Be sure to include line numbers.

PROGRAM	COMMENTS
`10 REMOTE 725`	Set up instrument for remote operation.
`20 OUTPUT 725; ''U0X''`	Send U0 status command.
`30 ENTER 725; A$`	Enter status word into computer.
`40 DISP''***DPCORZKT MDMEHY''`	
`50 DISP A$`	
`60 END`	

After entering the program, press the HP-85 RUN key. The U0 status word is then displayed on the CRT. Refer to Figure 4-1.

4.3.13 Prefix (G)

With the use of the G command, the prefix for the status word or data string can be either transmitted or deleted. The commands are as follows:

G0 = Include prefix
G1 = Suppress prefix

Upon power up or after a DCL or SDC command, the G0 mode is enabled.

Programming Example—Program the Model 580 to output a data string without the prefix.

PROGRAM	COMMENTS
`10 REMOTE 725`	Set up for remote operation.
`20 OUTPUT 725; ''G1X''`	Suppress prefix.
`30 ENTER 725; A$`	Enter command into the computer.
`40 DISP A$`	Display data string on CRT.
`50 END`	

To run the program, press the HP-85 RUN key. The data string appears on the CRT without the prefix (N+NP). Refer to Figure 4-3, which shows the data string format with the prefix.

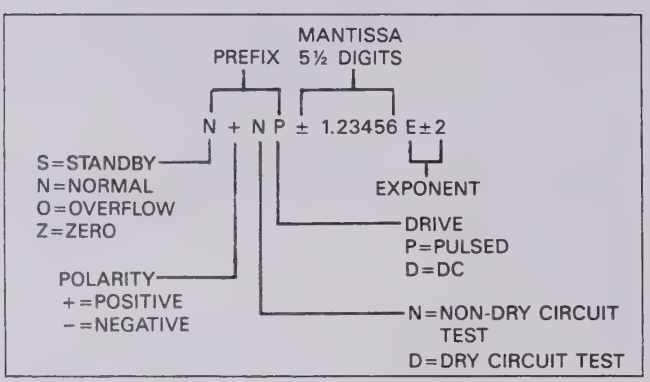


Figure 4-3. Data Format

4.3.14 Programmable Terminator (Y)

The Model 580 uses special terminator characters to mark the end of its data string or status word. To allow a wide variety of controllers to be used, the terminator can be changed by sending the appropriate command over the bus. The default value is the commonly used carriage return, line feed (CR LF) sequence. The terminator sequence assumes this default value upon power up or after the instrument receives a DCL or SDC.

The terminator may be programmed by sending the ASCII character Y followed by the desired terminator character. Any ASCII character except the following may be used:

1. Any capital letter.
2. Any number.
3. Blank
4. + − / , . or e

Special command characters will program the instrument for special terminator sequence as follows:

1. Y(LF) = CR LF (Two terminators)
2. Y(CR) = LF CR (Two terminators)
3. Y(DEL) = No terminator

NOTE

Most controllers use the CR or LF character to terminate their input sequence. Using a nonstandard terminator may cause the controller to hang up unless special programming is used.

Programming Example—The terminator can be eliminated by sending an ASCII DEL with the following HP-85 statements:

```
REMOTE 725
OUTPUT 725;"Y";CHR$(127);"X"
```

When the END LINE key is pressed the second time, the terminator is suppressed; no terminator is sent by the instrument when data is requested. The absence of the normal terminator may be verified by entering the following statement into the HP-85 computer:

```
ENTER 725;A$
```

At this point the HP-85 ceases to operate because it is waiting for the standard CR LF terminator sequence to terminate the ENTER statement. The computer may be reset by holding down the SHIFT key and pressing the RESET key on the keyboard. To return the instrument to the normal terminal sequence, enter the following statement into the HP-85 computer:

```
OUTPUT 725;"Y";CHR$(10);"X"
```

4.3.15 Data Format

Model 580 data is transmitted over the IEEE-488 bus as a string of ASCII characters with the format shown in Figure 4-3.

The first four characters indicate the function status of the Model 580. The first character shows if the unit is in standby (S), normal (N), overflow (O) or zero (Z); the second character indicates positive polarity (+) or negative polarity (−); the third character indicates if the unit is in Dry Circuit Test (D) or in non-Dry Circuit Test (N); and the fourth character indicates pulsed drive (P) or DC drive (D).

The mantissa of the reading is made up of eight characters, including sign and decimal point, while the exponent requires three characters. To obtain the data string from the instrument, the controller must perform the following sequence:

1. Set the ATN true (low).
2. Address the instrument to talk.
3. Set ATN false (high).
4. Input the data string one byte at a time.

NOTE

The data string can be transmitted without the prefix 580.

Programming Example—Cycle power on the Model 580 (turn it off, then on) and program it to output a data string.

PROGRAM	COMMENTS
`10 REMOTE 725`	Set up for remote operation.
`20 ENTER 725;A$`	Enter data string into controller.
`30 DISP A$`	Display data string on CRT.
`40 END`	

To run the program press the HP-85 RUN key.

4.4 TALK ONLY OPERATION

The talk only feature of the Model 580/5802 may be used to send data to a listen only device such as printer. When the Model 580 is in talk only, it ignores commands given over the IEEE-488 bus. Talk only is enabled by placing the TO/ADDRESSABLE switch of the primary address switch in the TO position (refer to Figure 3-7) and cycling power to the instrument. The talk rate is typically three readings per second, depending on the function. However, a different talk rate can be selected using an external trigger source by performing the following procedure:

1. Enable the listen only capability of the receiving device (such as a printer).
2. Connect the Model 580/5802 to the listen only device with an appropriate IEEE-488 cable.
3. Place the LSB (least significant bit) switch on the Model 5802 at 0 to send a prefix with the reading, or at 1 to send data only (suppress the prefix).
4. Power up Model 580 (again, default reading rate is three readings per second).
5. Press SHIFT, then SINGLE to put the instrument in one-shot. Now, every time SINGLE is pressed or an external trigger is received, a reading will be taken (up to the maximum reading rate of that function).

When the Model 580 is used in talk only, it may be interfaced with one or more listeners. Each of these devices and associated cables should conform to IEEE-488-1978 standards.

The Model 580 transmits its normal data string in bit parallel byte serial fashion over the bus as requested by the listeners. The data format used is the same one used for addressable operation and is described in detail in paragraph 4.3.15. If the address switches are set to an odd number the prefix is sent with the reading. An even address number sends only the data.

SECTION 5
ANALOG OUTPUT

5.1 INTRODUCTION

The analog output is an important feature of the Model 5802 IEEE-488 Interface. It is useful for monitoring the input signal with an external device such as a chart recorder. The analog signal is reconstructed from digital data (supplied by the internal microprocessor) by a 13 bit D/A converter. Because of this condition the analog output accurately reflects the display until an overflow condition is reached. The analog output is optically isolated from the Model 580 to avoid potential ground loop problems. There are two levels of gain for the analog output, the X1 gain and the X100 gain. Refer to paragraph 5.4.

On the X1 gain, 1V at the analog output corresponds to 10,000 counts on the Model 580 display. On the X100 gain, 1V at the analog output corresponds to 100 counts on the Model 580 display.

The accuracy of the analog output is ±0.25% of displayed reading +2mV, where 2mV in X100 = 0.2 displayed counts. Update of analog output is coincident with update of the display.

5.2 USING THE ANALOG OUTPUT

The analog output is useful for monitoring the input signal with an external device such as a chart recorder. Using the analog output connected to chart recorder produces a hardcopy of the input signal over a period of time.

1. Connect the measuring device to the two analog output terminals on the rear panel as shown in Figure 5-1.

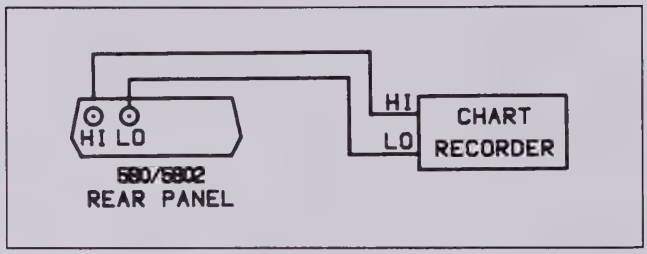


Figure 5-1. Analog Output Connections

CAUTION

The potential between the analog output LO terminal and earth ground must not exceed 30V RMS at DC, 50 or 60Hz peak. Make sure the external device does not exceed this voltage on its common or ground connections. Failure to observe this precaution may damage the Model 580/5802. IEEE-488 common is connected to analog output common.

WARNING

The potential between the SOURCE LO of the Model 580 and the analog output LO of the Model 5802 must not exceed 30V RMS at DC, 50 or 60Hz. Failure to observe this precaution may result in a dangerous potential being present on the analog output terminals and the IEEE-488 connector. This situation could result in personal injury or death.

2. Select the desired gain. The gain switch is located on the rear panel. A logic one (up position) is the X100 gain. A logic zero (down position) is the X1 gain.

   X1 gain—Set switch to logic 0.
   X100 gain—Set switch to logic 1.

   In the X1 position, the most significant ±2000 counts of the displayed reading can be covered. The span on this range (X1) is ±2V in 1mV steps. In the X100 position, the least significant 400 counts of the displayed reading can be covered. The span on this range is ±4V in 1mV steps.

3. If necessary, the analog output may be zeroed with the REL function. To do so, press the REL button on the front panel. All subsequent readings are referenced to the previously displayed value. Refer to the Model 580 Operator's Manual for complete details concerning the REL function.

The Model 580 displays an "OL" message when the capability of a specific range is exceeded. When this message is displayed and the X1 gain is selected, the analog output value is +2V if the polarity of the displayed value is positive and -2V if the display value is negative. The analog output value is ±4V respectively if the X100 gain is selected.

An analog output range overflow can occur when the Model 580 analog range switch is in the X1 position. An example of the analog output voltage under these conditions is shown in Figure 5-2. The conditions shown are for the Model 580 in the 200mΩ range, but the output reacts similarly on the other resistance ranges if the proper scaling is applied. For each tenfold increase in range, the scale of the horizontal axis must also be multiplied by a factor of ten.

The horizontal axis of Figure 5-2 has a range of -199.99mΩ to +199.99mΩ.

The analog output follows the display value linearly until the input resistance reaches 19999 counts (either positive or negative). The analog output then outputs the range overflow voltage of ±2V depending on the polarity of the display value.

A summary of analog output information is shown in Table 5-1. Each range of input values corresponds to the increment necessary to cause the analog output to go through its entire 0 to ±2V range.

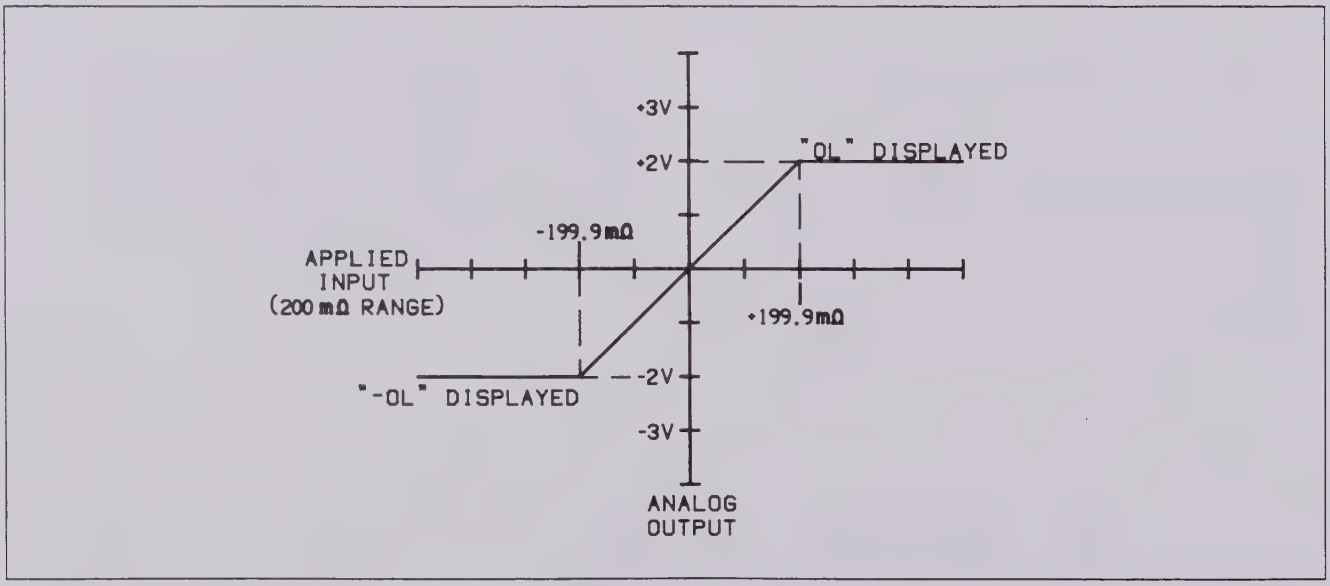


Figure 5-2. X1 Analog Output

Table 5-1. Analog Output Parameters

Range	Input for 1.99V Analog Output X1	Input for 4.00V Analog Output X100
200mΩ	199mΩ	4.00mΩ
2 Ω	1.99Ω	40.0mΩ
20 Ω	19.9Ω	400mΩ
200 Ω	199Ω	4.00Ω
2 kΩ	1.99kΩ	40.0Ω
20 kΩ	19.9kΩ	400Ω
200 kΩ	199kΩ	4.00kΩ

5.3 OUTPUT RESISTANCE

The output resistance of the analog output is 1kΩ. This is true for all ranges regardless of the gain status. Thus, loading problems caused by external devices are minimized. In order to keep loading errors below 1%, the input resistance of any device connected to the analog output should be greater than 100kΩ.

5.4 X100 RESOLUTION AND ACCURACY

In X100 the analog output increases the resolution of the Model 580 beyond the 4½ digits of the display. This provides an output step size of 2mV per each 0.2 counts of the displayed reading. For example, on the 200mΩ range, a 2mV step in the analog output voltage corresponds to a 2μΩ change in applied resistance to the Model 580. The extra resolution allows for a more continuous output.

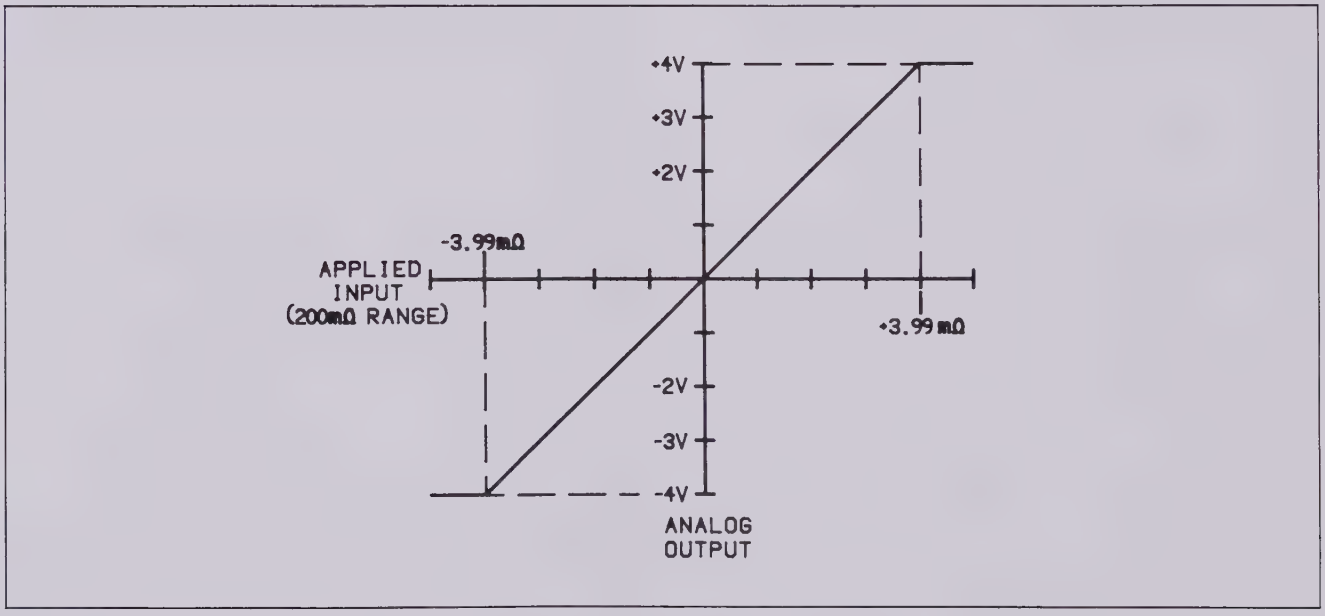


Figure 5-3. X100 Analog Output

SECTION 6
PRINCIPLES OF OPERATION

6.1 INTRODUCTION

This section contains a circuit description of the Model 5802 interface. The IEEE-488 interface option enables the Model 580 to be incorporated into a measurement system that utilizes programmed control through the IEEE-488 bus.

6.2 CIRCUIT DESCRIPTION

The entire IEEE-488 interface circuitry is located on a single board. The schematic number for the Model 5802 is 5802-106. Figure 6-1 shows a simplified block diagram of the interface. The following descriptions cover the power supply, digital circuitry and analog output circuitry.

6.2.1 Power Supply

The positive supply (V+) provides power to the +5V regulator VR104, U109 and U110. The supply voltage to U109, U110 and VR104 must be a minimum of +7.0V for V+ and -6.2V for V– to allow ample supply head room in order for the outputs to swing to their specified voltages. The negative supply V– is generated using C112, CR102, CR103 and C108 configured as a voltage inverter. During the positive going cycle of the line, CR102 is forward biased allowing C112 to charge to the peak voltage of the AC IN. CR103 is reversed biased. On the negative going line cycle CR102 is reversed biased and CR103 is forward biased allowing the charge on C112 to be transferred onto C108. Thus C108 is charged to -Vp (negative peak voltage).

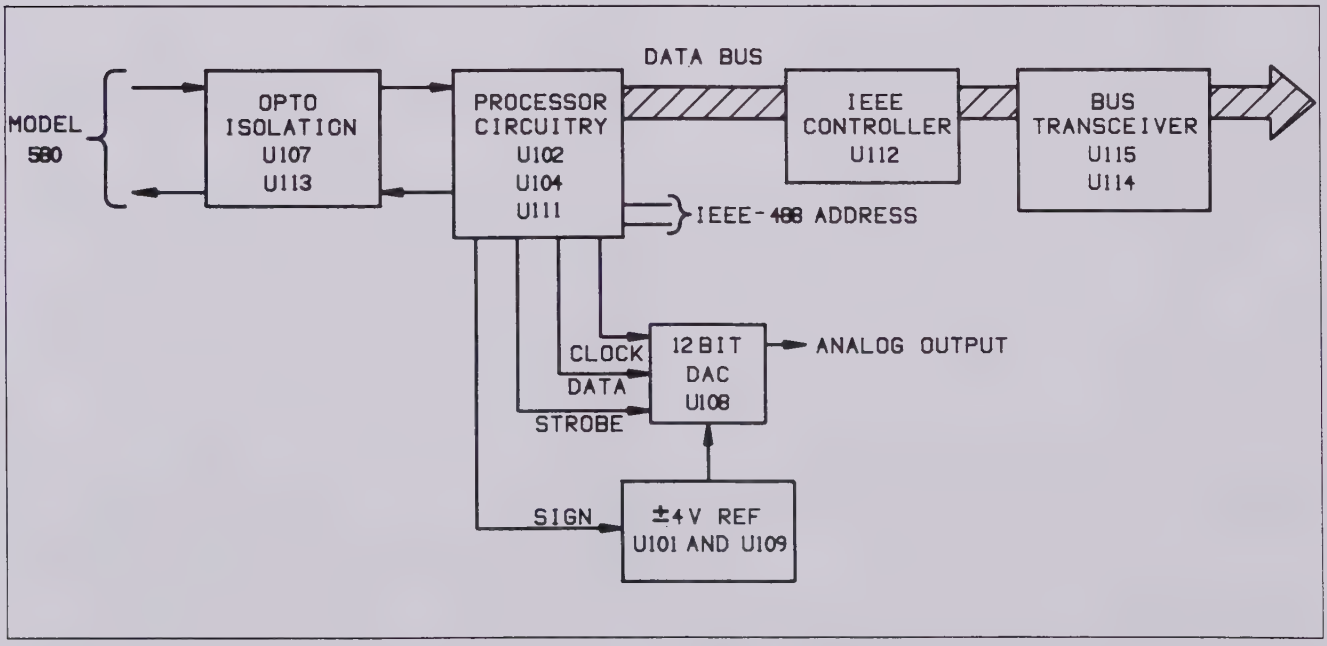


Figure 6-1. Simplified Block Diagram

6.2.2 Digital Circuitry

The digital circuitry consists of the microprocessor (U102), EPROM (U104), decoder (U111), IEEE-488 controller (U112) and bus transceivers (U114 and U115). Reset for the interface is accomplished by the internal reset feature of the microprocessor (U102) and its I/O line (PB1). Upon power up the microprocessor executes an internal reset routine. This cycle lasts 1920 clock cycles (one cycle = 800kHz = 1.25μsec). After configuring itself, the processor sets PB1 low then high. This resets the IEEE-488 controller (U112). Figure 6-2 shows the memory map for the interface.

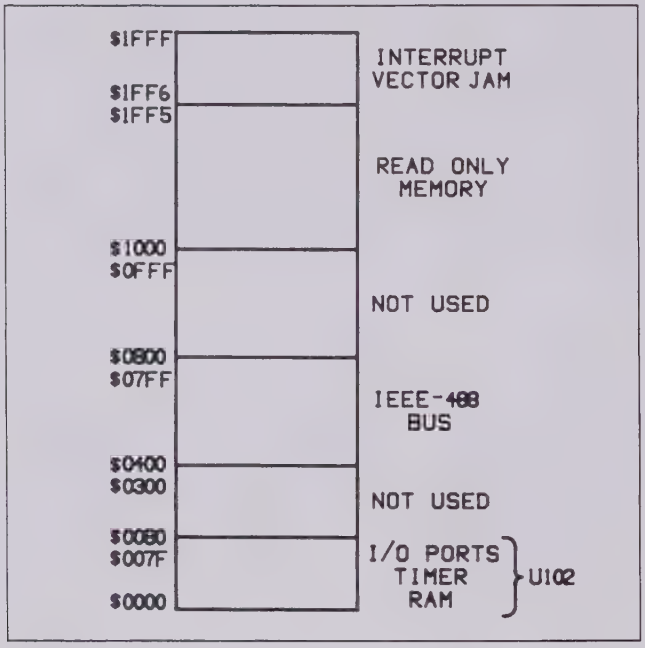


Figure 6-2. Memory Map

The interface is capable of performing all IEEE-488 talker/listener protocols. The bidirectional data lines D0 through D7 permit the transfer of data between the microprocessor and the bus. The transceivers are used to drive the output and also buffer the data.

The primary address switches (SW101) select the primary address and permit 31 primary talker/listener address pairs. To address the Model 580, the controller must send the primary address of the Model 580. The factory set address is 25 (11001). The microprocessor reads the primary address from SW101 and then knows which talker/listener address to assign the IEEE-488 controller and thus the Model 580.

NOTE

The primary address is updated only upon power up.

The address switch is read through Port A (PA2-PA6) of U102.

6.2.3 Analog Output

The analog output of the Model 5802 is derived from the displayed reading of the Model 580. This reading is sent over the opto interface to the Model 5802. The digital reading is then transformed to an analog output by a 13 bit DAC (digital-to-analog converter) on the Model 5802.

The DAC is composed of a 12 bit serial input monolithic CMOS multiplying DAC and a ±4V polarity switchable reference. The output of the DAC is given by:

$$V_{out} = -V_{ref} \frac{\text{12 bit word}}{4096}$$

Data is sent to the serial input DAC over three control lines (Data, Clock and Strobe). The DATA is clocked into the DAC on the rising edge of the clock. Once all 12 bits have been sent, pulling the strobe line low forces the output of the 12 bit DAC to a level corresponding to the new DAC input. The polarity of the 4V reference is controlled by the processor through U101, Q101 and Q102. For a positive reference voltage, the sign bit is low, allowing +5V to be switched to the gate of Q101 grounding the anode of VR101. For a negative reference, the sign bit is high, gate voltage to Q102 is high and the cathode of VR101 is pulled to the ground. U109 acts as a X3.2 buffer to boost the reference voltage from ±1.25V to ±4V.

The analog output allows selectable gains, X1 or X100. In X1, the most significant ±2000 counts of the display are used for determining the output. In X100, the least significant ±400 counts of the display (and an internal digit) are used for determining the output. See Figure 6-3. The extra resolution allows a continuous analog output.

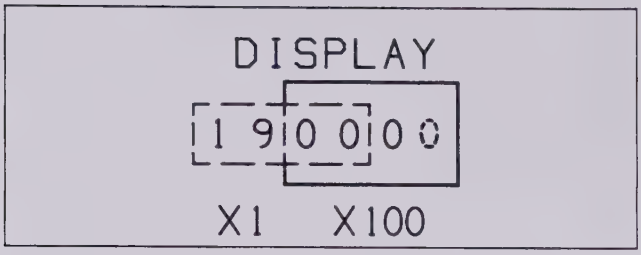


Figure 6-3. X1 and X100 Gains

Opto-isolators U109 and U111 electrically isolate the Model 580 from the Model 5802 interface. This isolation allows the Model 580 to maintain its 30V common mode floating specification. The specification is maintained even if the interface is referenced to the IEEE-488 controller ground.

The output of the DAC varies between −1.999V and +1.999V in X1 and −3.999 and +3.999 in X100. An overload condition results in an output of ±1.999V in X1 and ±3.999V in X100 respectively.

SECTION 7
MAINTENANCE

7.1 INTRODUCTION

This section contains information necessary to maintain the Model 5802 IEEE-488 Interface. Installation procedures, troubleshooting information and instructions concerning care in handling static sensitive devices are included.

WARNING

All service informarion is intended for qualified electronic maintenance personnel only.

7.2 INSTALLATION

The Model 5802 is field installable. To install the interface into the Model 580 use the following procedure and refer to Figure 7-1.

WARNING

To prevent shock hazard, turn off the Model 580, remove all test leads from the instrument and unplug the line cord.

1. Remove and retain the top cover. The top cover is secured by four screws that are accessible from the bottom of the instrument.
2. Install the rear standoff (ST-171-1) by positioning it over the hole on PC board as shown in Figure 7-1, and pressing firmly until it snaps securely into the board.
3. Position the interface board loosely on the rear standoff.

WARNING

Do not push down on the white Molex connector (J1008). The male connector pins will pass through J1008 and may cause personal injury.

4. Guide the terminals of P1008 into J1008 and firmly push down on that end of the board to mate the connectors.
5. Push down on the other side of the interface board until it snaps onto the rear standoff. Make sure the board is seated properly on the front standoffs.
6. Install the modified top cover.

WARNING

If the interface is removed, use the original top cover supplied with the Model 580 (if available). If the modified top cover is used, cover the holes normally occupied by the IEEE-488 connector and switch. Failure to cover these holes could result in a shock hazard that could cause severe injury or death.

At this point, it is necessary to recalibrate the Model 580 to maintain rated accuracy specifications. If the instrument is not recalibrated at this time, add +0.01% to the Model 580 accuracy specifications (these can be found on the first page of the Model 580 Operator's and Service Manual). Refer to the Model 580 Service Manual for calibration procedures if the 580/5802 is to be recalibrated.

7.3 5802 CALIBRATION

Calibration of the Model 5802 should be performed every 12 months. If any of the calibration procedures in this section cannot be performed properly, refer to the troubleshooting information in this section. If the problem persists, contact your Keithley representative or the factory for further information.

7.3.1 Warm Up

The Model 580, with the Model 5802 installed, requires one hour for warm up to achieve rated specifications. The top cover must be installed.

7.3.2 Recommended Calibration Equipment

Calibration of the Model 5802 may be done with the equipment listed below. Alternate equipment may be used but the specifications must be at least as accurate as the specifications that follow:

4½ digit DMM --with ±(0.03% + 1 count) accuracy on 2V range with greater than 10MΩ input resistance (Keithley Model 175)

Resistance Calibrator: Fluke Model 5450A

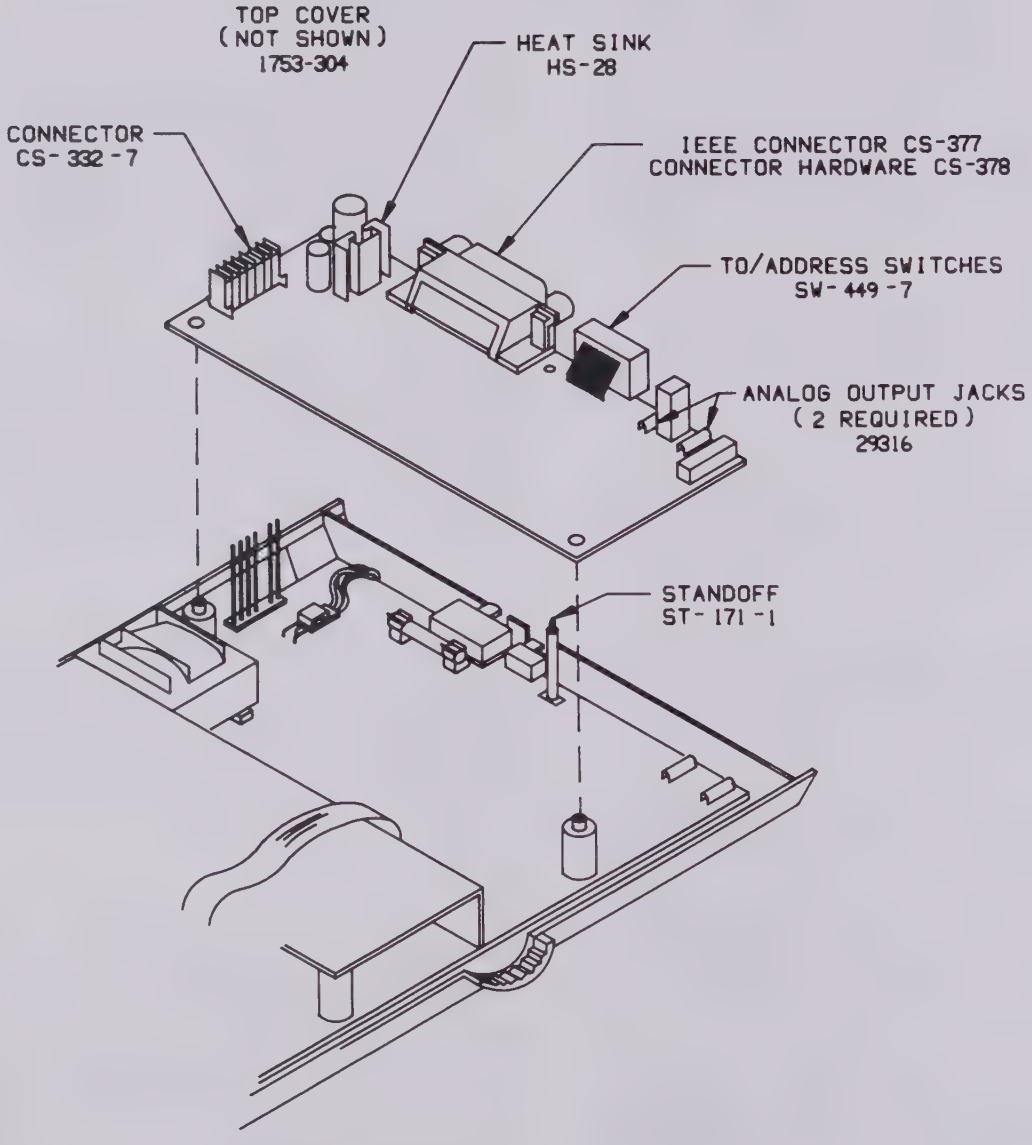


Figure 7-1. Model 5802 Installation

7.3.3 Environmental Conditions

Calibration should take place in laboratory conditions having an ambient temperature of 23°C ±3°C and a relative humidity of less than 70%. If the instrument has been subjected to temperatures outside of this range or to higher humidity allow at least one additional hour for the instrument to stabilize before beginning calibration procedure.

7.3.4 Calibration

Perform the following steps to calibrate the Model 5802.

1. Turn on the instrument and allow one hour for warm up.
2. Select the 2kΩ range. Set the Model 5802 for the X1 gain.
3. Apply 1.9kΩ to the Model 580 input.
4. Measure the analog output voltage with the 4½ digit DMM.
5. Adjust R112 until the analog output reads 1.9000 ±0.0004V.
6. Model 5802 calibration is now complete.

7.4 SPECIAL HANDLING OF STATIC SENSITIVE DEVICES

MOS and CMOS devices are designed to function at very high impedance levels. Normal static charge can destroy these devices. Table 7-1 lists all the static sensitive devices for the Model 5802. Steps 1 through 7 provide instruction on how to avoid damaging these devices.

1. Devices should be handled and transported in protective containers, antistatic tubes or conductive foam.
2. Use a properly grounded work bench and a grounding wrist strap.
3. Handle the devices only by the body. Do not touch the pins.
4. The PC boards must be grounded to the bench while inserting devices.
5. Use antistatic solder suckers.
6. Use grounded tip soldering.
7. After devices are soldered or inserted into sockets, they are protected and normal handling may resume.

7.5 TROUBLESHOOTING

The troubleshooting information in this section is intended for use by qualified personnel who have a basic understanding of the analog and digital circuitry used in an IEEE-488 interface. Instructions have been written to assist in isolating the defective circuit. Isolating the defective component has been left to the technician. Refer to Table 7-2 for IEEE-488 interface board checks.

NOTE

For instruments that are still under warranty (less than 12 months since date of shipment), if performance falls outside specification at any point, contact your Keithley representative or the factory before attempting troubleshooting or repair.

Table 7-1. Static Senstive Devices

Circuit Designation	Keithley Part No.
U101	IC-283
U102	LSI-60
U103	IC-341
U104	5802-800
U105, U106	IC-106
U108	IC-419
U111	IC-338

Table 7-2. Model 5802 Interface Checks

NOTE

All voltages are referenced to ANALOG OUTPUT common except steps 1 and 2 which are referenced to instrument digital common.

Step	Item/Component	Required Condition	Remarks
1	J1008 Pin 1 referenced to Pin 2	+5V ±10%	+5V Instrument Digital Supply
2	U106 Pins 2, 4, 6 and 10	0V to 5V data pulses.	
3	VR104 OUT	+5V ±10%	+5V IEEE Digital Supply
4	VR104 IN	+8.5V ±10%	+V
5	CR103 Anode	−8.5V ±10%	−V
6	S101 (1-7)	In the "1" position the switch is pulled up to +5V ±10%	Primary Address
7	U102 Pin 4	0V to +5V pulses at ≈800kHz rate.	DS (data strobe)
8	U102 Pin 6	0V to +5V pulses at ≈800kHz rate.	AS (address strobe)
9	U102 Pin 2	+5V Level	IRQ Line
10	U112 Pin 19	+5V Level	RESET Line
11	Program the Model 580 into the Remote Mode (primary address 25)		
12	U114 Pins 19 and 2	0V to +0.5V	REN Line (low true)
13	U114 Pins 18 and 3	+5V +10%, pulsed low when an IFC command is sent.	IFC Line
14	U114 Pins 4 and 17	Handshaking sequence, refer to paragraph 2.3.2.	NRFD Line
15	U114 Pins 16 and 5	Handshaking sequence, refer to paragraph 2.3.2.	NDAC Line
16	U114 Pins 15 and 6	Handshaking sequence, refer to paragraph 2.3.2.	DAV Line
17	U114 Pins 14 and 7	+5V ±10%, pulsed low at the end of multi-byte transfer sequence in the K0 mode.	EOI
18	U114 Pins 13 and 8	0V to +.5V when processing multiline commands.	ATN Line
19	U114 Pins 12 and 9	0V to +0.5V when SRQ condition exists. Refer to paragraph 4.3.8.	SRQ Line
20	U105 Pins 4, 6, 10, 12 and 15	0V to 5V data pulses.	
21	U102 Pin 34	+5V Pulses	Strobe Line (analog out)
22	U102 Pin 33	+5V Pulses	Data Line (analog out)
23	U102 Pin 36	+5V Pulses	Clock Line (analog out)
24	U102 Pin 35	+5V pulsed low during power up.	RESET Line
25	U109 Pin 6	±4V ±0.002%	−4V for positive display; +4V for negative display
26	U109 Pin 3	±1.25V ±2.5%	−1.25V for positive display; +1.25V for negative display

SECTION 8
REPLACEABLE PARTS

8.1 INTRODUCTION

This section contains replacement parts information, component location drawings and schematic diagrams for the Model 5802.

8.2 REPLACEABLE PARTS

Parts are listed alphanumerically in order of the schematic designation. Table 8-1 contains parts list information for the Model 5802.

8.3 ORDERING INFORMATION

To place and order, or to obtain information concerning replacement parts, contact your Keithley representative or the factory. See the inside front cover for addresses. When ordering include the following information:

1. Instrument Model Number
2. Instrument Serial Number
3. Part Description
4. Circuit Description (if applicable)
5. Keithley Part Number

If an additional instruction manual is required, order the manual package (Keithley part number 5802-901-00). The manual package includes an instruction manual and all pertinent addenda.

8.4 FACTORY SERVICE

If the instrument is to be returned to the factory for service, carefully pack the unit and include the following:

1. Complete the service form which follows this section and return it with the instrument.
2. Advise as to the warranty status of the instrument (see inside front cover for warranty information).
3. Write the following on the shipping label: ATTENTION REPAIR DEPARTMENT.

8.5 SCHEMATIC DIAGRAMS AND COMPONENT LOCATION DRAWINGS

The component location drawing of the Model 5802 is shown in Figure 8-1. The schematic diagram of the Model 5802 is shown in Figure 8-2.

Table 8-1. Model 5802 Parts List

Circuit Desig.	Description	Schematic Location	Keithley Part No.
C101	Capacitor, 4.7μF, 25V, Aluminum Electrolytic	B4	C-314-4.7
C102	Capacitor, 22pF, 100V, Ceramic Disc	B3	C-22-22p
C103	Capacitor, 22pF, 100V, Ceramic Disc	B3	C-22-22p
C104	Capacitor, 0.1μF, 50V, Ceramic	E1	C-365-.1
C105	Capacitor, 0.1μF, 50V, Ceramic	C1	C-365-.1
C106	Capacitor, 100pF, 100V, Ceramic Disc	B4	C-22-100p
C107	Capacitor, 100pF, 100V, Ceramic Disc	A3	C-22-100p
C108	Capacitor, 250μF, 25V, Aluminum Electrolytic	C5	C-314-250
C109	Capacitor, 0.1μF, 50V, Ceramic Film	H3	C-237-.1
C110	Capacitor, 0.1μF, 50V, Ceramic	D5	C-365-.1
C111	Capacitor, 2200μF, 16V, Aluminum Electrolytic	C5	C-351-2200
C112	Capacitor, 250μF, 25V, Aluminum Electrolytic	C5	C-314-250
C113	Capacitor, 1μF, 50V, Metalized Polyester	A2	C-350-1
C114	Capacitor, 0.1μF, 50V, Ceramic	A3	C-365-.1
CR101	Bridge Rectifier, Silicon	C5	RF-52
CR102	Rectifier	C5	RF-38
CR103	Rectifier	C5	RF-38
J1014	IEEE-488 Connector	H3	CS-377
J1008	7-Pin Molex Connector	C5	CS-332-7
J1012	Jack	A2	29316
J1013	Jack	A3	29316
K101	Relay	E4	RL-83
Q101	Transistor, N-Channel Enhancement MOSFET	B5	1972-600
Q102	Transistor, N-Channel Enhancement MOSFET	A5	1972-600
R101	Resistor, 10MΩ, 5%, ¼W, Composition	C3	R-76-10M
R102	Resistor, 10kΩ, 5%, ¼W, Composition	D5	R-76-10k
R103	Resistor, 30.1kΩ, 1%, 1/8W, Metal Film	B5	R-88-30.1k
R104	Resistor, 19.6kΩ, 1%, 1/8W, Metal Film	B4	R-88-19.6k
R105	Resistor, 29.4kΩ, 0.1%, 1/8W, Fixed	A4	R-176-29.4k
R106	Resistor, 10kΩ, 1%, 1/8W, Metal Film	A4	R-177-10k
R107	Resistor, 100kΩ, 5%, ¼W, Composition	D5	R-76-100k
R108	Resistor, 330Ω, 5%, ¼W, Composition	D6	R-76-330
R109	Resistor, 10kΩ, 5%, ¼W, Composition	E5	R-76-10k
R110	Resistor, 100kΩ, 5%, ¼W, Composition	E5	R-76-100k
R111	Resistor, 330Ω, 5%, ¼W, Composition	E5	R-76-330
R112	Potentiometer, 5k	A4	RP-89-5k
R113	Resistor, 1kΩ, 10%, ½W, Composition	A2	R-1-1k
R114	Thick Film Resistor Network	B1	TF-99
S101	Bank of 7 Dip Switches (Primary Address)	B2	SW-449-7
U101	Triple 2-Channel Analog Multiplexer, CD4053BC	B3	IC-283
U102	CMOS 8 Bit Microprocessor, 146805E2	C2	LSI-60
U103	Triple 3-Input NAND Gate, MM74HC10	D2	IC-341
U104*	4k × 8 ROM	E2	5802-800-**
U105	Hex Inverter, 4049	C5	IC-106

*Order current software level (i.e., 5802-800-A1)

Table 8-1. Model 5802 Parts List (Cont.)

Circuit Desig.	Description	Schematic Location	Keithley Part No.
U106	Hex Inverter, 4049	E5	IC-106
U107	Opto Coupler, TIL117	E5	IC-362
U108	Serial Input 12-Bit DAC, 7543KN	B2	IC-419
U109	Op Amp, 308A	B4	IC-203
U110	Op Amp, 308A	A3	IC-203
U111	Octal D Latch, 74HC373	E3	IC-338
U112	GPIB Adapter, 9914	G3	LSI-49
U113	Opto Coupler, TIL117	E6	IC-362
U114	GPIB Transceiver, 75161	G4	IC-299
U115	GPIB Transceiver, 75160	G2	IC-298
VR101	Diode, Band Gap Reference, 1.25V	B5	DZ-65
VR102	Diode, Zener, 5.1V	A3	DZ-59
VR103	Diode, Zener, 5.1V	A3	DZ-59
VR104	+5V Regulator, LM340A	D5	IC-93
Y101	Crystal, 4.0MHz	C3	CR-10

ZONE	LTR	ECO NO	REVISION	ENG	DATE
	A	10939	RELEASED	CB	10/14/85
	B	11183	ENG'D PC ARTWORK WAS REV. C. ADDED ITEM 17, C-314-4.7MF ITEM 49, R76-10K(R115)	JG	2-27-86

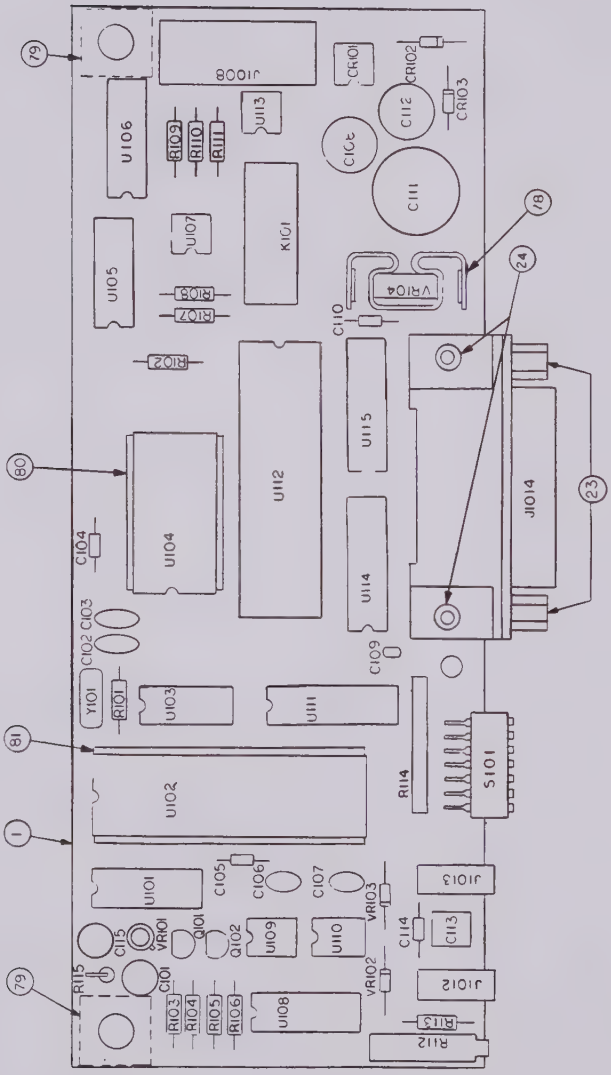
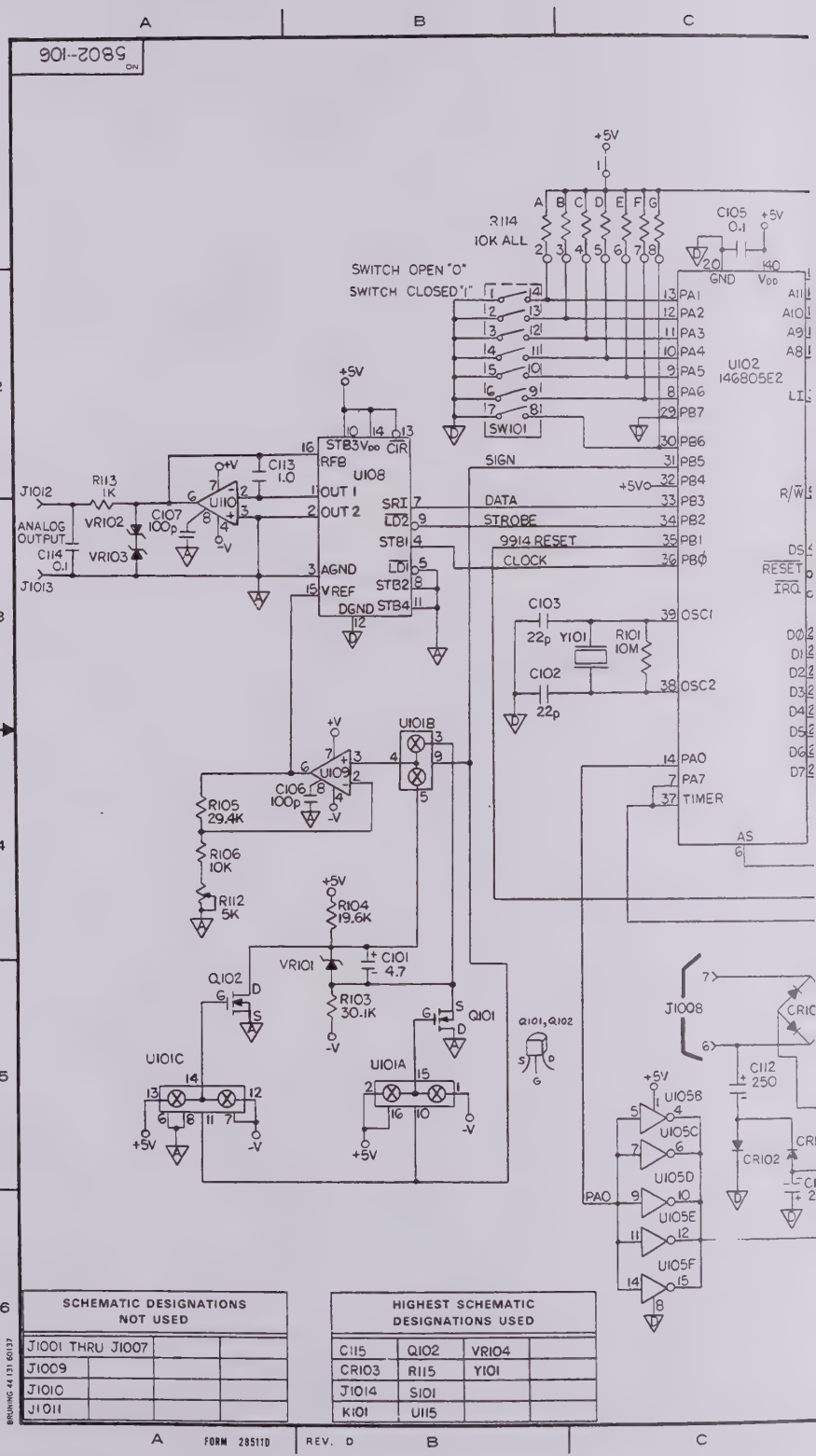


Figure 8-1. Model 5802 Interface, Component Location Drawing, Dwg. No. 5802-100


5802-106 ON
A
B
C
+5V
R114 10K ALL
SWITCH OPEN "0"
SWITCH CLOSED "1"
SW101
C105 0.1
U102 146805E2
GND
VDD
PA1
PA2
PA3
PA4
PA5
PA6
PB7
PB6
PB5
PB4
PB3
PB2
PB1
PBØ
OSC1
OSC2
PA0
PA7
TIMER
AS
SIGN
DATA
STROBE
9914 RESET
CLOCK
U108
STB3
RFB
OUT 1
OUT 2
AGND
VREF
DGND
SRI
LD2
STB1
LD1
STB2
STB4
CIR
VDD
C113 1.0
R113 1K
J1012
ANALOG OUTPUT
C114 0.1
J1013
VR102
VR103
C107 100p
U110
C103 22p
Y101
R101 10M
C102 22p
U101B
U109
C106 100p
R105 29.4K
R106 10K
R112 5K
R104 19.6K
VR101
C101 4.7
R103 30.1K
Q102
Q101
Q101, Q102
U101C
U101A
J1008
C112 250
CR102
U105B
U105C
U105D
U105E
U105F
SCHEMATIC DESIGNATIONS NOT USED
J1001 THRU J1007
J1009
J1010
J1011
HIGHEST SCHEMATIC DESIGNATIONS USED
C115
Q102
VR104
CR103
R115
Y101
J1014
S101
K101
U115
BRUNING 44 131 60137
FORM 28511D
REV. D

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